July 31, 2026

To: Readers of this Final EIS

Publication of this Final EIS comes at a crucial time in the modern history of the Colorado River Basin (Basin).

The need for sound water management strategies is of the utmost importance. The Colorado River Basin provides drinking water and power for over 40 million people, irrigation water for over 5 million acres of agricultural land and supports vital ecosystems across the seven Colorado River Basin states covering broad areas in the southwestern United States. In addition, on the other side of our southern border, two northern Mexico states rely on the Colorado River for essential municipal and agricultural water supplies. Several of the major reservoir- and water-management documents and agreements developed to guide Colorado River operations expire in 2026. The Secretary of the Interior, acting through the Bureau of Reclamation, proposes adoption of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating ranges to take effect when the current agreements expire in 2026. For the past 26 years, the Basin has been experiencing an unprecedented multi-decadal drought, resulting in historically low runoff and reservoir levels. During 2026, hydrologic conditions in the Basin have worsened; since publication of the Draft Environmental Impact Statement in January, it has become clear that the Basin will likely experience the lowest observed snowpack on record.

For decades, the Basin has relied on a reservoir system that has been able to buffer the impact of severe droughts by capturing and storing water during high flow periods. However, the extremely low hydrologic conditions over the past two and a half decades coupled with meeting water demands (albeit somewhat reduced by conservation and other activities) have resulted in very low conditions at the two largest reservoirs in the Basin, Lake Mead and Lake Powell. The combined contents of Lake Mead (behind Hoover Dam) and Lake Powell have not been this low since before Lake Powell began filling after the closure of the gates at Glen Canyon Dam in 1963.

Furthermore, current low Basin reservoir conditions, particularly at Lake Powell, have highlighted risks that could compromise the reliability and operational flexibility of Glen Canyon Dam that would affect the future ability to meet critical downstream water supply needs.

Since 2021, Colorado River operations have included a series of extraordinary operations designed to protect the infrastructure at Glen Canyon Dam and support continued reliable operations. Additional water from upstream reservoirs has been released to Lake Powell, and releases from Lake Powell to the Lower Basin have been reduced. This has been a coordinated and successful effort to date to keep Lake Powell above the critical elevation of 3,490 feet.

In the spring of this year, the Department of the Interior (Department) implemented unprecedented measures, including a decision to release 660,000 to 1 million acre-feet of additional flows from Flaming Gorge reservoir and reducing releases from Lake Powell to the Lower Basin down to 6 million acre-feet (a 1.5-million-acre-foot reduction). Despite all of these measures, due to the continued prolonged drought and water demands, the risk to the system has never been greater.

After a 2020 review of the preceding two decades of operations of Glen Canyon Dam and Hoover Dam, the Department began engaging the public to develop new operating guidelines that recognize the need to reduce water use in the Basin while protecting water delivery systems. Critical to this process, the Department and Bureau of Reclamation engaged extensively with the Basin States, Basin Tribes, and other

interested parties in pursuit of developing consensus-based long-term operational guidelines. Unfortunately, as of the publication of this Final Environmental Impact Statement, consensus on long-term operations has not been reached.

The Department published a Draft EIS in January 2026 because new operations must begin October 1, 2026. Due to the lack of consensus, the Draft EIS did not include a preferred alternative, preserving the opportunity for entities in the Colorado River to keep negotiating and reach consensus. In July, after another six months of negotiations since publication of the Draft EIS, no long-term consensus-based operation has been reached, and the Department must complete the NEPA process in order to have Colorado River operations in place for October 1, 2026.

The absence of a Basin consensus on water management strategies coupled with the ever-increasing hydrologic risk highlights the importance of the Secretary of the Interior's (Secretary) operational responsibilities under federal law to coordinate operations of Colorado River facilities and allow these facilities to meet their congressionally authorized purposes over the long term.

The Secretary has the statutory responsibility to make decisions about Colorado River operations that are based on actual hydrologic conditions, that consider conditions across the Basin as a whole, and that use flexible and responsive water management tools to protect operations at mainstem facilities, avoid operational risks to infrastructure at Glen Canyon Dam, and manage risks to the urban, agricultural, and natural systems that rely on the Colorado River. These responsibilities are particularly profound with reservoirs at historic low levels and declining river runoff anticipated to continue or worsen.

It is against this backdrop of hydrologic risk and lack of consensus that the Secretary has prepared the Preferred Alternative contained in this Final EIS for operations of Glen Canyon and Hoover Dams. The Preferred Alternative establishes an adaptive decision framework that will be used to develop operating guidelines that are designed to ensure reliable operations while being able to respond to changing conditions over a 10-year period.

The Preferred Alternative establishes a wide range of operations that provides the flexibility to develop specific operating guidelines within the 10-year period while preserving the opportunity for Basin negotiations to continue and, if successful, be incorporated in future operations.

The need for a flexible adaptive framework is clear given the history of the Basin since 2000. As reservoir elevations continued to fall and risk continued to increase, a series of interdependent agreements involving local, State, tribal and federal governments, water users and non-governmental organizations in both the United States and Mexico have enabled the system to operate by negotiated agreement rather than court determinations. Agreements have often included voluntary conservation programs and activities, demonstrating the capacity of the Basin to take necessary and innovative action to benefit reservoir storage. Today, Lake Mead is approximately 150 feet higher because of these agreements, and more conservation is planned in the coming years.

Maintaining the ability to negotiate and implement a consensus-based alternative remains a priority because a consensus-based solution is the most reliable way to ensure that operations balance the differing needs of water users across the entire Basin. This is particularly true as poor hydrology and reduced reservoir storage exacerbate longstanding disputes among Colorado River water users.

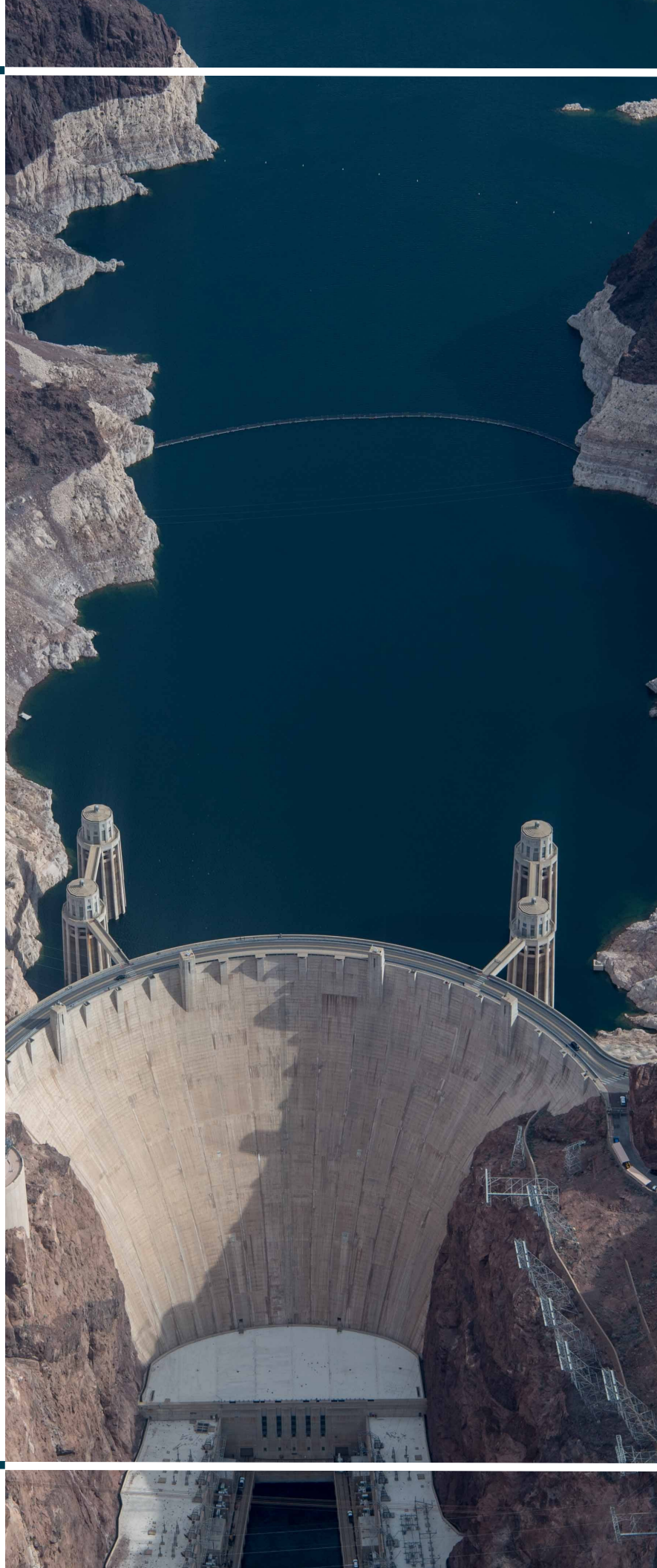
However, given the lack of consensus to date, decisions still need to be made for operations in the coming water year beginning October 1, 2026. The Preferred Alternative provides for flexible operations while creating opportunities for Basin entities to work together to achieve lasting Basin-wide solutions centered around cooperation, innovation, and partnerships.

BUREAU OF
RECLAMATION

Final Environmental Impact Statement

Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

Executive Summary



July 2026
U.S. Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Basins
Interior Regions 7 and 8

BUREAU OF
RECLAMATION

Mission Statements

The **Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo: Alexander Stephens / Bureau of Reclamation, 2018

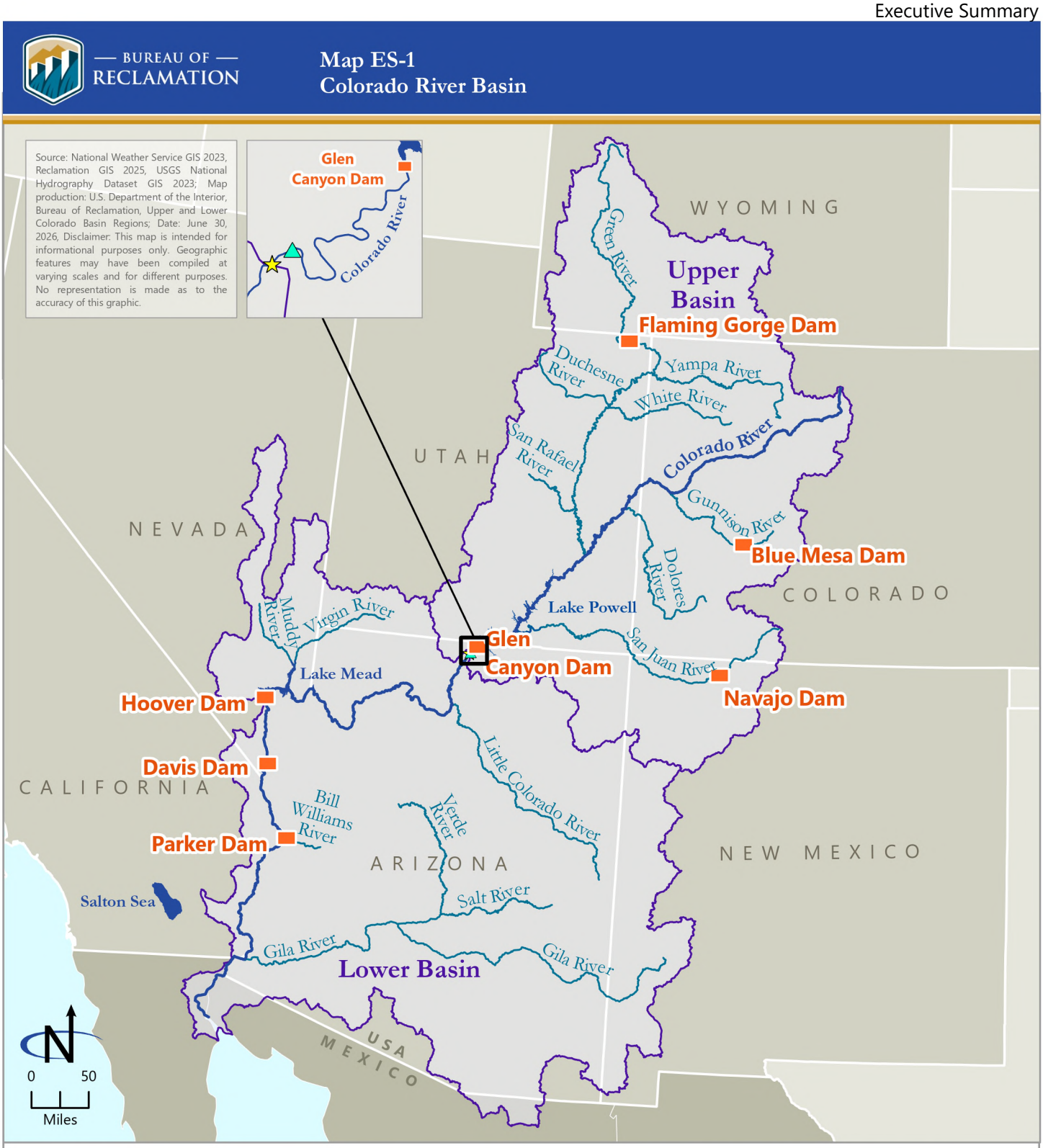
Executive Summary

ES.1 Background

The Colorado River Basin (Basin) provides essential water supplies to approximately 40 million people, nearly 5.5 million acres of agricultural lands, and habitat for ecological resources across seven states which includes broad areas in the Southwestern United States (U.S.) and Northwestern United Mexican States (Mexico) (**Map ES-1**). Prudent management of the Basin is critically important because the Colorado River is the foundation for diverse resources across a large geographic region and faces exceptional challenges from prolonged drought and future uncertainty. States, tribes, and Mexico rely on the Colorado River to support essential municipal, agricultural, environmental, cultural, and hydropower needs. These resources are now at significant risk: since the onset of the current drought in 2000, the Basin's primary reservoirs, Lake Powell and Lake Mead, have fallen to historically low elevations. Several of the major reservoir- and water-management documents and agreements developed to guide Colorado River operations through the persistently dry conditions expire in 2026, including the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines; Reclamation 2007), the 2019 Colorado River Drought Contingency Plans (Reclamation 2019), and key international agreements between the U.S. and Mexico. Despite the significance of these agreements, actions taken over the past two decades have not been sufficiently robust to prevent continued decline of the reservoirs through the prolonged drought.

The Secretary of the Interior (Secretary), acting through the Bureau of Reclamation (Reclamation), proposes adoption of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating ranges to take effect when the current agreements expire in 2026. Management strategies will primarily focus on the operation of Glen Canyon Dam and Hoover Dam but may include actions upstream and downstream of these facilities to protect critical reservoir elevations, such as releases from the Colorado River Storage Project (CRSP) Upper Initial Units to increase the elevation at Lake Powell, and approaches to enhance opportunities for Lower Colorado River Basin (Lower Basin) water users to reduce water use (see **Map ES-1**).

This Final Environmental Impact Statement (EIS) has been prepared to inform the Secretary's timely adoption of a new set of objective guidelines that improve predictability to all water users and managers in the Basin. Developing new guidelines is difficult in this complex Basin, where critically low storage in Lake Powell and Lake Mead, significant hydrologic variability, and the anticipation of drier future conditions amplify the central tradeoff: balancing the potentially profound impacts of water-delivery reductions with the need to maintain reservoir storage. The alternatives in this Final EIS capture a broad range of management strategies to address this tradeoff, and they demonstrate that there are multiple ways to find a balance if conditions improve. If conditions do not improve, achieving a balance is more difficult, and, under critically dry futures, even large and unprecedented reductions may be needed and may not be enough to stabilize storage.


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Map ES-1
Colorado River Basin
Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: June 30, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.
Glen Canyon Dam
Colorado River
WYOMING
Green River
Upper Basin
Flaming Gorge Dam
Duchesne River
Yampa River
White River
UTAH
San Rafael River
Colorado River
Gunnison River
Blue Mesa Dam
NEVADA
Dolores River
COLORADO
Muddy River
Virgin River
Lake Powell
Glen Canyon Dam
San Juan River
Navajo Dam
Lake Mead
Hoover Dam
Davis Dam
Little Colorado River
CALIFORNIA
Bill Williams River
Verde River
Parker Dam
NEW MEXICO
ARIZONA
Salton Sea
Salt River
Gila River
Gila River
Lower Basin
USA
MEXICO
N
0
50
Miles
Major dam
Lee Ferry Compact Point
Lees Ferry Gaging Station
Colorado River
Major Colorado River tributary
Colorado River Basin, Upper and Lower Basins
States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

Consistent with the Department of the Interior's (Department) longstanding preference for consensus-based management of the Colorado River System, the Department and Reclamation engaged extensively with the Basin States,[1] Basin Tribes,[2] and other interested parties during development of successor operating guidelines over the course of 4 years. However, despite those efforts, the Basin States did not reach consensus on long-term guidelines prior to the completion of this EIS. Accordingly, rather than adopting long-term operating guidelines of the same duration as the 2007 Interim Guidelines, the Secretary proposes in the Preferred Alternative to adopt an operational strategy consisting of an adaptive decision framework to develop operating guidelines for Lake Powell and Lake Mead for operating years 2027 through 2036. This framework provides for more robust operational provisions than the current guidelines while preserving the flexibility to respond to changing hydrologic conditions and to incorporate future consensus recommendations, should they be reached.

Reclamation, as the agency designated to act on the Secretary's behalf with respect to operation of Glen Canyon Dam and Hoover Dam and managing the mainstream waters of the lower Colorado River in accordance with federal law, is the lead federal agency for the purposes of compliance pursuant to the National Environmental Policy Act of 1969 (NEPA), as amended, for the development and implementation of the proposed interim guidelines. Five federal agencies are cooperating for purposes of assisting with environmental analysis and preparation of this EIS. The cooperating agencies are the Bureau of Indian Affairs, National Park Service, U.S. Fish and Wildlife Service, U.S. Section of the International Boundary and Water Commission (IBWC), and Western Area Power Administration. The Final EIS is organized into four volumes:

Volume I – EIS with the following chapters:

Chapter 1: Purpose and Need. Provides the background of Colorado River operations and describes why federal action is needed.

Chapter 2: Description of Alternatives. Describes the process of formulating alternatives, describes the Preferred Alternative, and presents a range of reservoir operation strategies and guidelines considered under each alternative. A summary of the performance tradeoffs between alternatives is provided at the end of Chapter 2.

Chapter 3: Affected Environment and Environmental Consequences. Describes the existing environmental conditions and evaluates potential impacts that could result from implementation of the alternatives.

Chapter 4: Consultation and Coordination. Describes public and stakeholder involvement process during the preparation of this Final EIS.

[1] Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming

[2] There are 30 federally recognized Native American tribes in the Basin: Ak-Chin Indian Community, Chemehuevi Indian Tribe, Cocopah Indian Tribe, Colorado River Indian Tribes, Fort McDowell Yavapai Nation, Fort Mojave Indian Tribe, Fort Yuma-Quechan Tribe, Gila River Indian Community, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Jicarilla Apache Nation, Kaibab Band of Paiute Indians, Las Vegas Paiute Tribe, Moapa Band of Paiute Indians, Navajo Nation, Pascua Yaqui Tribe, Pueblo of Zuni, Salt River Pima-Maricopa Indian Community, San Carlos Apache Tribe, San Juan Southern Paiute, Shivwits Band of Paiutes, Southern Ute Indian Tribe, Tohono O'odham Nation, Tonto Apache Tribe, Ute Indian Tribe of the Uintah and Ouray Reservation, Ute Mountain Ute Tribe, White Mountain Apache Tribe, Yavapai-Apache Nation, and Yavapai-Prescott Indian Tribe.

Volume II – Supporting appendices, primarily focused on modelling information, including modeling assumptions, analytical methods, and supporting calculations.

Volume III – Technical appendices for each of the environmental resources discussed in Chapter 3. These appendices provide supporting and more detailed information.

Volume IV – List of persons contributing to the preparation of this Final EIS, list of references cited in this Final EIS, glossary of commonly used terms, and index.

ES.1.1 Purpose and Need for Action

The proposed federal action is needed for the following reasons:

- *The Secretary is legally required to coordinate operations of Colorado River reservoirs:* The Colorado River Basin Project Act of 1968 directs the Secretary to adopt criteria for the coordinated long-range operation of Colorado River reservoirs. In compliance with this obligation, the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968 (Long-Range Operating Criteria [LROC]; Colorado River Basin Project Act of 1968 [CRBPA]; Reclamation 1970) were developed and adopted by the Secretary in 1970. The LROC provides general narrative guidance regarding Lake Powell and Lake Mead operations but does not contain specific, objective criteria to guide annual operations. To address this inadequacy, the 2007 Interim Guidelines were developed to provide objective criteria used by the Department to implement the LROC. The 2007 Interim Guidelines have provided the predictability needed by the entities that receive Colorado River water to better plan for and manage available water supplies from the Colorado River and other sources.
- The *2007 Interim Guidelines are expiring:* Current operational guidelines expire during the 2026 operating year. The Department has determined that specific, objective operational guidelines are important to provide improved predictability and should be established for another interim period beyond 2026. Most of the federal and non-federal agreements associated with implementing provisions of the 2007 Interim Guidelines also expire after the 2026 operating year.
- *The 2007 Interim Guidelines have not sufficiently reduced risk:* Based on operational experience since 2007, the current guidelines are not robust enough to manage the system in a way that is sufficiently protective of the resources dependent on the Colorado River. Despite near-continuous drought-response actions in recent years, low reservoir conditions have persisted, and new infrastructure risks at Glen Canyon Dam have arisen. More robust and adaptive guidelines are needed for the efficient and sustainable management of the major mainstream Colorado River reservoirs and system resources.
- *Imbalance between water supply and demand will be exacerbated by increasingly likely low-runoff conditions:* The Basin is experiencing increased aridity due to climate variability, and long-term drought and low-runoff conditions are expected in the future. These conditions will exacerbate the now widely recognized imbalance between water supply and demand in the Basin. Robust and flexible guidelines are needed to manage the Colorado River system and its resources under a broad range of potential future hydrologic conditions.
- *Expanded and innovative use of conservation is needed:* Recognizing the anticipated future low-runoff conditions in the Basin, the Department has also determined a need for guidelines that provide

Colorado River water users, including Basin Tribes, expanded opportunities to conserve, store,exchange, and take subsequent delivery of water in and from Lake Mead and/or Lake Powell. The guidelines should also support and integrate future efficiency improvements and opportunities for augmentation.

- *Addressing tribal concerns regarding Basin management is needed:* Basin Tribes have expressed concern that the current approach to Colorado River water management is insufficient to address the range of interests, needs, and fundamental rights of the Basin Tribes. The Department has determined a need for guidelines that provide flexibility and predictability for Basin Tribes to remain able to benefit from their water rights and have opportunities to participate in voluntary conservation programs.

The purpose of the proposed federal action is to:

- Update and expand management guidelines for Colorado River reservoirs, particularly for the coordinated operation of Lake Powell and Lake Mead
- Provide Colorado River water users a greater degree of predictability with respect to annual water availability in future years under anticipated increasing variability, low runoff, and low reservoir conditions
- Provide additional mechanisms for the conservation, exchange, storage, and delivery of water supplies in Colorado River reservoirs to increase the flexibility to meet water use needs
- Provide new or enhanced opportunities for Basin Tribes to benefit from their water rights
- Provide flexibility to build resilience and accommodate future needs and growth that are supported by Colorado River water supplies, including the integration of unquantified tribal water rights once they are resolved

ES.1.2 Proposed Federal Action

Reclamation, acting on behalf of the Secretary, proposes to adopt guidelines and coordinated reservoir management strategies to address operations of Lake Powell and Lake Mead through their full operating ranges. This action would improve predictability to all water users and managers in the Basin by developing and adopting objective guidelines for the operation of Glen Canyon Dam and Hoover Dam to take effect when the current operating guidelines expire in 2026. This action is designed to provide for the sustainable management of the Colorado River system and its resources under a wide range of potential future system conditions.

The proposed federal action considers the following operational elements that are collectively designed to address the purpose and need for the proposed federal action:

1) Identification of circumstances under which the Secretary would allocate the annual amount of water available for consumptive use from Lake Mead to the Lower Division states (Arizona, California, and Nevada) at, below, or above 7.5 million acre-feet (maf), pursuant to the Supreme Court Decree in *Arizona* v. *California,* 376 U.S. 340 (1964) (Final Decree entered in 2006).
2) Coordinated operations of Lake Powell and Lake Mead, particularly under low reservoir conditions.
3) Storage and delivery of conserved water in Lake Mead and/or Lake Powell to increase the flexibility to meet water use needs from both reservoirs, including the storage and delivery of

non-system water; exchanges; and water conserved through extraordinary measures by or for tribal, agricultural, or municipal entities.

The proposed federal action allows for development of robust operating guidelines for Lake Powell and Lake Mead without precluding upstream or downstream actions needed to protect critical reservoir elevations at Lake Powell and Lake Mead, such as the following:

- Approaches that consider total system storage in all major Colorado River reservoirs and/or actual inflows to determine coordinated operations of Lake Powell and Lake Mead.
- Approaches that include opportunities for conservation, augmentation, demand management, or other water management strategies (such as exchanges or transfers).
- Modified operations at upstream CRSP Upper Initial Units[3] to release additional water if needed to protect critical infrastructure at Glen Canyon Dam.

The Secretary intends that the guidelines be interim in nature and extend for the same duration as the 2007 Interim Guidelines (approximately 20 years). Adoption of new guidelines for an interim (or limited) period provides the opportunity to gain additional experience for operating the reservoirs, thereby informing future operational and water management decisions.

Recognizing additional authorities may be developed, the Department intends to adopt and implement the guidelines in a manner consistent with the Law of the River. The Department also intends that the guidelines be used to implement the LROC and applicable federal law through the issuance of the Annual Operating Plan for Colorado River Reservoirs.

ES.1.3 Geographic Scope

Consistent with the geographic scope analyzed in the 2007 Interim Guidelines Final EIS, the geographic scope that would be affected by the proposed federal action begins at full pool of Lake Powell at Gypsum Canyon and extends downstream along the mainstream Colorado River floodplain to the Southerly International Boundary (SIB) with Mexico. This proposed federal action would also potentially affect interests of water users in the Lower Division States in service areas that extend beyond the mainstream of the Colorado River.

Although the proposed federal action is focused on Lake Powell and Lake Mead operations, management strategies that include activities upstream of Lake Powell are being analyzed in this Final EIS. These activities include Upper Colorado River Basin (Upper Basin) conservation and, if warranted to protect critical reservoir elevations, coordinated operations of the CRSP Upper Initial Units to release additional water within their respective Records of Decision (RODs) to increase the elevation at Lake Powell. Operations at the CRSP Upper Initial Units specifically contemplated in this Final EIS are intended to remain within the scope of the existing RODs.[4] Since those RODs are covered by their own NEPA, this Final EIS does not need to expand the geographic scope of analysis

[3] CRSP Upper Initial Units include Flaming Gorge, Blue Mesa (a component of the Aspinall Unit), and Navajo reservoirs. Current RODs governing operations of these units were signed in 2006, 2012, and 2006, respectively.

[4] While the Secretary will consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the CRSP Upper Initial Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes as stated in the 1956 Colorado River Storage Project Act.

upstream of Lake Powell. With respect to Upper Basin conservation, the nexus to the proposed federal action is the storage and delivery of that conserved water in Lake Powell. The effects of this storage in and delivery from Lake Powell are within the scope of the EIS, while specific activities that may be undertaken in the Upper Basin to generate the conserved water are not within the scope of this EIS. Any such activities are unknown at this time and will not necessarily require federal decision making. Any federal decisions associated with these conservation activities will be assessed outside of this EIS.

ES.2 Alternatives

ES.2.1 Alternative Development

The process of developing the range of alternatives was informed by solicitation of input and extensive collaborative engagement with stakeholders throughout the Basin. This took place over a two-and-a-half-year period beginning with publication of the Scoping Report in October 2023 through publication of this Final EIS.

During the public involvement periods and the rest of the alternatives development process, Reclamation received considerable input from the Basin States, many Basin Tribes, conservation organizations, other federal agencies, other stakeholders, and members of the public. Input submitted ranged from detailed proposed alternatives to operational concepts and principles. Throughout the alternatives development phase, Reclamation met continuously with states, tribes, and other partners to review and discuss their input. For those proposals containing sufficient detail to be considered as a full alternative or a major component of an alternative, Reclamation worked extensively with these entities to not only understand and gather additional information, but also to model and perform preliminary analyses of their proposals to facilitate refinements. Additionally, Reclamation developed an online platform, the Post-2026 Operations Exploration Web Tool, allowing stakeholders, interested parties, and the public to independently or collaboratively design operational strategies to inform their input to the NEPA process.

On January 9, 2026, the Environmental Protection Agency published a notice in the *Federal Register* (91 *Federal Register* 2131) announcing the availability of the Draft EIS and beginning a public comment period that ran through March 2, 2026. Since Draft EIS publication, the Department has also continued to work with the Basin States and Basin Tribes to facilitate development of a consensus agreement. Despite this extensive engagement, a long-term consensus-based approach to Basin reservoir operations has not yet been achieved.

This Final EIS analyzes a No Action alternative and five action alternatives that incorporate over 4 years of input provided by stakeholders and the public and received through consultations with the Basin States and Basin Tribes. These alternatives capture a broad range of operational concepts and potential environmental impacts:

- Preferred Alternative (added since publication of the Draft EIS)
- No Action Alternative
- Basic Coordination Alternative
- Enhanced Coordination Alternative

- Maximum Operational Flexibility Alternative
- Supply Driven Alternative

ES.2.2 The Preferred Alternative

In the absence of a long-term consensus-based approach, Reclamation has developed a Preferred Alternative and analyzed it in this Final EIS. The Preferred Alternative is a 10-year decision framework. The decision framework establishes operational principles, sideboards (key thresholds and ranges for operational elements), and a process that would govern development and issuance of operating guidelines covering anticipated 2-year intervals, unless consensus-based agreements provide for a longer duration. The framework does not establish specific operating guidelines; rather, it provides the structure within which operating guidelines would be developed, reviewed, and periodically updated through 2036.

The decision framework in the Preferred Alternative offers a vehicle for continued work toward sustainable management in the Basin. It provides continuity following the expiration of the 2007 Interim Guidelines; establishes transparency and predictability for future decision making; preserves flexibility to respond to changing hydrology and evolving Basin circumstances; facilitates incorporation of future Basin consensus recommendations; and is consistent with applicable federal law. The framework (principles, sideboards, and process) would remain constant through 2036, unless modified through future federal action and appropriate environmental compliance.

ES.2.2.1 Operating Guidelines

Operating guidelines are the objective criteria that determine the operations of Lake Powell and Lake Mead for the anticipated 2-year interval. For each interval, the framework process would be carried out to develop and issue operating guidelines in accordance with the principles and sideboards described below. The operating guidelines would be adopted through the issuance of a decision document published in the *Federal Register*. Once issued, the operating guidelines would be implemented through Annual Operating Plans.

ES.2.2.2 Operational Principles

The operational principles are designed to ensure that operating guidelines adopted under the framework adhere to fundamental management priorities and provide a basis for review and reflection as new operating guidelines are developed.

The operational principles are listed below:

1. *Operations should be responsive to hydrology.* Annual operations and mid-year adjustments that account for evolving supply conditions should be adopted to ensure a flexible, adaptive approach to management.
2. *Critical federal infrastructure must be protected through practical and deliberate operations.* When Lake Powell is projected to fall below elevation 3,500 feet or when Lake Mead is projected to fall below elevation of 1,000 feet, processes and tools will be used to manage risks to infrastructure and prevent damage to federal facilities of regional and national importance. These elevations reflect current understanding of these facilities but do not preclude the identification of alternate or additional critical elevations.

3. *Operating guidelines should implement the LROC while also providing directions to address extraordinary circumstances.* Operating guidelines will provide objective criteria for operating under low reservoir conditions within the bounds of the LROC but may also provide for temporary operational actions that are not otherwise provided for under the LROC when necessary to protect critical federal infrastructure in accordance with applicable federal law.
4. *Operating guidelines should prioritize consensus-based recommendations.* The Department will support efforts to achieve consensus agreements that appropriately provide benefits to multiple parties, that offer innovative, inclusive solutions to operational and management challenges, and that are sufficiently protective of the system. Should such agreements arise, they will be prioritized as new operating guidelines are developed and adopted. In the absence of consensus-based arrangements, the Secretary will take the necessary management actions, consistent with applicable federal law.

ES.2.2.3 Operational Sideboards

The decision framework's operational sideboards are key thresholds and ranges for the four operational elements (described below) that create boundaries for the development of each set of operating guidelines and provide a basis for environmental compliance for the duration of the decision framework. The sideboards defined in **Table ES-1** were chosen to appropriately balance tradeoffs among resources and ensure that the Department would have the flexibility and environmental compliance to operate in accordance with the operational principles given future hydrologic uncertainty.

Table ES-1
Operational Sideboards for the Preferred Alternative

Operational Element	Operational Ranges
Lower Basin Shortage Guidelines	Up to 3.0 maf to provide protection of critical infrastructure at Hoover Dam in dry hydrologic conditions The allocation of shortages would be based on applicable law, including the Consolidated Decree. Deviation from applicable law would occur only if water entitlement holders have reached voluntary arrangements Consultation would occur if projected Lake Mead elevation < 1,000 ft to determine potential additional reductions to Lower Basin water deliveries
Coordinated Reservoir Operations	5.0 maf to 12.0 maf Lake Powell WY releases to provide protection for critical infrastructure at Glen Canyon Dam and sufficiently high releases necessary to prevent spill avoidance releases Consultation would occur if projected Lake Powell elevation < 3,500 ft to determine potential additional actions
Storage and Delivery of Conserved System and Non-system Water	Lake Powell: up to 3.0 maf Lake Mead: up to 8.0 maf (supports existing ICS, new ICS-type program, conservation pools, and exchange mechanisms)
Lower Basin Surplus Guidelines	Up to 500 kaf in addition to Flood Control and Quantified Surplus

Operational Element	Operational Ranges
Additional Activities Above Lake Powell	Potential for maximum use of CRSP Upper Initial Units within their respective RODs to release additional water if needed to protect critical infrastructure
	Voluntary Upper Basin contributions up to 200 kaf per year subject to hydrologic conditions

In contrast to the specified operations under the other alternatives analyzed in this Final EIS, the Preferred Alternative is designed to create the opportunity for subsequent decision making; because of this distinction, it is appropriate to include a modeling representation of operating guidelines that may be developed under the Preferred Alternative. The sideboards provide a basis for understanding the range of potential impacts, and analyzing these potential impacts provides a necessary and instructive comparison to the other alternatives included in this Final EIS. Taken together, the representation of the operational elements described below is referred to and analyzed in this Final EIS as the "Representative Preferred Alternative." The Representative Preferred Alternative is a set of modeling assumptions designed around the Preferred Alternative sideboards to approximate the range of operating guidelines that may be adopted for each interval during the 10-year framework. The specifications in the operational elements reflect how the Representative Preferred Alternative was modeled; exact operations would be subject to the guidelines in place during each interval and would adhere to consultation triggers.

ES.2.2.4 Process

Each set of operating guidelines would be implemented and evaluated through a process during which Reclamation would work with stakeholders to seek consensus, align with operational principles and sideboards, and account for system conditions, hydrology, and other Basin developments.

ES.2.3 Summary of Alternatives

Each alternative is comprised of four operational elements: (1) Guidelines to Reduce or Increase Deliveries from Lake Mead, (2) Coordinated Reservoir Operations (Lake Powell and Lake Mead), (3) Storage and Delivery of Conserved System and Non-System Water, and (4) Additional Activities Above Lake Powell. Each element is varied across the alternatives providing a reasonably broad range of Colorado River operations that capture an appropriate range of potential environmental impacts. **Table ES-2** summarizes the representation of these elements in the No Action Alternative and the five action alternatives considered and evaluated in this Final EIS.

Table ES-2
Summary Comparison of Alternatives

Preferred Alternative (Including Representation of Operational Elements)

The Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals, unless consensus-based agreements provide for a longer duration. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS, and each set of guidelines would be developed based on operational principles and fit within the framework's defined operational sideboards (thresholds and ranges for operational elements). The sideboards provide a basis for assumptions included in the Representative Preferred Alternative summarized in this table, which captures the range of operating guidelines that may be adopted during each interval. Lake Powell releases range from 5.0 maf to 12.0 maf depending primarily on Lake Powell elevation. Lower Basin shortages up to 3.6 maf (including assumptions about reductions to Mexico) are distributed using a combination of LB Priority (up to 1.5 maf, 2027-2028) and priority.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3, 4]	Coordinated Reservoir Operations (Lake Powell and Lake Mead)	Storage and Delivery of Conserved System and Non-system Water[3]	Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]	Additional Activities Above Lake Powell
• Shortages up to 3.6 maf (including assumptions about reductions to Mexico) • In 2027-2028, shortages up to 1.5 maf are distributed based on the distribution developed by the Lower Division States and shortages exceeding 1.5 maf are distributed based on priority (Approach 1 of the Supply Driven Alternative) • After 2028, shortages are distributed based on priority, unless agreements are reached • Consultation to determine additional reductions if projected Lake Mead elevation is less than 1,000 feet	• Lake Powell releases determined based on Lake Powell elevation unless equalization releases are required • Releases range from 5.0 to 12.0 maf, unless more is required for equalization releases • Consultation to determine additional actions if projected Lake Powell elevation is less than 3,500 feet	• Storage up to 7.0 maf in Lake Mead with additional 1.0 maf Federally Managed Water Resources Pool; included for purposes of determining Lower Basin surplus and Shortage Conditions, as well as equalization releases from Lake Powell • Storage up to 3.0 maf at Lake Powell; included for purposes of determining Lake Powell releases • Existing ICS converted to new mechanism immediately • Expanded flexibilities: interstate exchanges within each basin, new tribal mechanism	• Surplus determinations based on Lake Mead elevation at or above 1,165 feet, 70R (spill avoidance strategy) or Flood Control conditions	• Potential maximum use of CRSP Upper Initial Units within their respective RODs to release additional water if needed to protect critical infrastructure at Glen Canyon Dam contingent on hydrologic conditions • Trigger additional releases when projected Lake Powell elevation is less than 3,525 feet • Voluntary Upper Basin contributions up to 200.0 kaf per year subject to hydrologic conditions

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[4] As noted in **Section 2.4**, the anticipated guidelines for the first operating interval as of publication of this Final EIS are preliminary. Modeling assumptions for 2027-2028 regarding shortage distribution reflect the May 1, 2026, Lower Division States proposal. As described in **Table 2-1**, Operational Sideboards, absent voluntary arrangements, the distribution of shortages would be based on applicable law (i.e., the priority system). This distribution is modeled in the Representative Preferred Alternative for years 2029 and beyond. Both distribution methods are documented and analyzed in **Appendix C**, Shortage Allocation Model, and **Chapter 3**. Regarding maximum shortage volume, modeling assumptions provide for reductions above the 1.25 maf maximum if needed to avoid critically low elevations at Lake Mead.

No Action Alternative

The No Action Alternative is included as a requirement of NEPA. Operations would revert to annual determinations announced through the Annual Operating Plan. Pursuant to the LROC, the objective is to maintain a minimum release of water from Lake Powell of 8.23 maf, therefore Lake Powell releases are assumed to be 8.23 maf[1] unless a higher release is required for equalization or a lower release occurs due to Glen Canyon Dam infrastructure limitations.[2] Shortages to the Lower Basin would be based on priority and reach a maximum of 600.0 thousand acre-feet (kaf). This would not represent a continuation of current operations but is generally based on the operating guidance that was in place before the adoption of the 2007 Interim Guidelines. While the authority to use CRSP Upper Initial Units to respond to exigent and emergency conditions was recognized at that time, no specific framework for such activities had been developed, so no defined activities are included in this alternative. Existing Intentionally Created Surplus (ICS) would be delivered in accordance with existing agreements, but there would be no new storage and delivery mechanisms.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)**	**Storage and Delivery of Conserved System and Non-system Water[3]**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
• Shortages determined based on Lake Mead elevation • Shortage volume of 400.0, 500.0, and 600.0 kaf at elevations 1,075, 1,050, and 1,025 feet, respectively • Shortages distributed based on priority	• Lake Powell release of 8.23 maf unless more is required for equalization releases • Releases less than 8.23 maf below elevation 3,490 feet due to Glen Canyon Dam infrastructure limitations	• No new storage and delivery mechanism to replace ICS • Delivery of existing ICS in accordance with existing agreements	• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions	• No specific additional activities above Lake Powell defined

[1] Article II(2) of the LROC states the "objective shall be to maintain a minimum release of water from Lake Powell of 8.23 [maf]." Reclamation recognizes that entities in the Basin have different legal positions regarding how this LROC statement incorporates other Law of the River elements to determine annual releases. Reclamation also recognizes that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted.

[2] Releases from Glen Canyon Dam may be unable to achieve the specified annual release volume when Lake Powell is below elevation 3,490 feet due to infrastructure constraints. Modeling assumptions for all alternatives reflect this constraint (see **Appendix A**).

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

<table>
<tr><td>Basic Coordination Alternative</td><td colspan="5">This alternative is designed to be implementable absent new agreements among Basin water users. Lake Powell releases would primarily be 8.23 maf, with some releases above and below 8.23 maf, and minimum releases of 7.0 maf. Lake Powell elevations could be increased by releases from CRSP Upper Initial Units within their respective RODs to protect infrastructure at Glen Canyon Dam. Reclamation would identify triggers for when additional Upper Basin actions are needed to protect critical infrastructure. Lower Basin shortages up to 1.48 maf would be triggered based on Lake Mead elevation and distributed consistent with priority system. Existing ICS would be delivered in accordance with existing agreements, but there would be no new delivery and storage mechanisms.</td></tr>
<tr><td></td><td>Shortage Guidelines to Reduce Deliveries from Lake Mead[3]</td><td>Coordinated Reservoir Operations (Lake Powell and Lake Mead)</td><td>Storage and Delivery of Conserved System and Non-system Water[3]</td><td>Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]</td><td>Additional Activities Above Lake Powell</td></tr>
<tr><td></td><td>• Shortages based on Lake Mead elevation up to 1.48 maf
• Shortages distributed based on priority
• Identify conditions when additional reductions may be needed to avoid reaching critically low elevations</td><td>• Lake Powell releases are determined based on Lake Powell elevation unless equalization releases are required
• Releases range from 7.0 to 9.5 maf, unless more is required for equalization releases
• Identify conditions when additional action may be needed for infrastructure protection</td><td>• No new storage and delivery mechanism to replace ICS
• Delivery of existing ICS in accordance with existing agreements</td><td>• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions</td><td>• Releases from CRSP Upper Initial Units within their respective RODs and contingent on hydrologic conditions to protect infrastructure at Glen Canyon Dam
• Identify conditions when additional Upper Basin actions may be needed for infrastructure protection</td></tr>
</table>

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Enhanced Coordination Alternative

This alternative is based on concepts from Basin Tribes, federal agencies, and other stakeholders to achieve protection of critical infrastructure while benefitting key resources (e.g., natural, hydropower and recreation) through an approach to distributing storage between Lake Powell and Lake Mead. Lake Powell releases would be determined based on a combination of Lake Powell and Lake Mead elevations, 10-year running-average hydrology, and Lower Basin deliveries. This alternative would include storage and delivery mechanisms for Lake Powell and Lake Mead and extensive flexibilities for all users. The operations incorporate Basin-wide shared contributions to the system, including Upper Basin conservation that would be stored in Lake Powell and Lower Basin shortages starting at 1.3 maf, approximately the average annual evaporative and system losses at and below Lake Mead, and reaching a maximum of 3.0 maf. Shortages would be triggered based on combined storage in Lake Powell and Lake Mead and distributed pro rata.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)**	**Storage and Delivery of Conserved System and Non-system Water[3]**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
• Shortages determined based on combined storage in Lake Powell and Lake Mead • Shortages begin at 60% full at a volume of 1.3 maf, then increase linearly, reaching a maximum of 3.0 maf at 30% full and below • Shortages distributed pro rata	• Lake Powell releases determined based on a combination of Lake Powell and Lake Mead elevations, 10-year running-average hydrology, and Lower Basin deliveries • Releases range from 4.7 to 10.8 maf	• Storage up to 5.0 maf in Lake Mead with additional 2.0 maf Protection Pool; included for purposes of determining Lake Powell releases and shortages • Storage up to 2.0 maf in Lake Powell; included for purposes of determining Lake Powell releases but excluded from shortage determinations • Existing ICS converted to new mechanism immediately • Extensive flexibilities for all users: intra- and interstate transactions within each basin • Tribal water (both conserved consumptive use and unused) including in Lake Powell conservation pool and Lake Mead Protection Pool	• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions	• Upper Basin conservation contributed to the Lake Powell conservation pool based on hydrologic conditions: up to 200.0 kaf per year for first 5 years, up to 275.0 kaf per year for second 5 years, up to 350.0 kaf starting in year 11

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Maximum Operational Flexibility Alternative

This alternative is informed by a proposal submitted by a consortium of conservation organizations and incorporates proactive responses, targeted reservoir management strategies, and innovative and flexible tools to address an increasingly variable set of future hydrologic conditions. Lake Powell releases would range from 5.0 to 11.0 maf and would be determined by total CRSP system storage and recent hydrology. Releases would switch to "run-of-river" when Lake Powell is at 3,510 feet or lower. The operations incorporate Basin-wide shared contributions, including up to 4.0 maf of shortages in the Lower Basin triggered by combined seven-reservoir storage (CRSP Upper Initial Units, Lake Mead, Lake Mohave, and Lake Havasu) and recent hydrology and voluntary water contributions from both basins.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)[3]**	**Storage and Delivery of Conserved System and Non-system Water**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
• Shortages determined based on combined seven-reservoir storage and recent hydrology • Shortages start at 80% full and increase linearly, subject to upward adjustment based on hydrology, reaching a maximum of 4.0 maf • Shortages distributed based on priority, as described in Approach 1 of the Supply Driven Alternative	• Lake Powell releases determined based on total Upper Basin system storage and recent hydrology • Releases subject to downward adjustment based on hydrology and range from 5.0 to 11.0 maf • Releases switch to "run-of-river" when Lake Powell is at elevation 3,510 feet or lower	• Storage up to 8.0 maf in either Lake Powell or Lake Mead; excluded for purposes of determining Lake Powell releases and shortages • Existing ICS converted to new mechanism over 5 years • Extensive flexibilities for all users: transactions within and across basins, including interstate and inter-basin	• Surplus determinations limited to Flood Control conditions	• Average of 200.0 kaf of Upper Basin annual conservation based on hydrologic conditions contributed to the Lake Powell conservation pool

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

<table>
<tr><td>Supply Driven Alternative</td><td colspan="5">Annual Lake Powell releases are determined based on a 65 percent of 3-year-average natural flow at Lees Ferry. Lake Powell elevations could be increased by releases from CRSP Upper Initial Units within their respective RODs to protect infrastructure at Glen Canyon Dam. This alternative would include new delivery and storage mechanisms for Lake Powell and Lake Mead. Lower Basin shortages up to 2.1 maf would be triggered based on Lake Mead elevation. This alternative analyzes two approaches to shortage distribution: state-based combined with Lower Basin-wide priority and state-based combined with Lower Basin-wide pro rata.</td></tr>
<tr><td></td><td>Shortage Guidelines to Reduce Deliveries from Lake Mead[3]</td><td>Coordinated Reservoir Operations (Lake Powell and Lake Mead)</td><td>Storage and Delivery of Conserved System and Non-system Water[3]</td><td>Surplus Guidelines to Increase Deliveries/Releases from Lake Mead[3]</td><td>Additional Activities Above Lake Powell</td></tr>
<tr><td></td><td>• Shortages determined based on Lake Mead elevation
• Shortages start at 1,145 feet and reach a maximum of 2.1 maf at 1,000 feet and below
• Shortages distributed using two approaches: LB Priority and LB Pro Rata</td><td>• Lake Powell releases determined primarily based on 65% of 3-year natural flows at Lees Ferry
• Releases range from 4.7 to 12.0 maf</td><td>• Storage up to 8.0 maf in Lake Mead; excluded for purposes of determining shortages
• Storage up to 3.0 maf at Lake Powell; included for purposes of determining Lake Powell releases
• Existing ICS converted to new mechanism over 10 years
• Expanded flexibilities: interstate exchanges within each basin</td><td>• Surplus determinations based on Lake Mead elevation at or above 1,165 feet, 70R (spill avoidance strategy) or Flood Control conditions</td><td>• Increased releases from CRSP Upper Initial Units by up to 500.0 kaf per year within their respective RODs and contingent on hydrologic conditions to protect infrastructure at Glen Canyon Dam
• Up to 200.0 kaf of Upper Basin annual conservation based on hydrologic conditions contributed to the Lake Powell conservation pool
• In years when Lake Powell cannot meet its required water year release because of low elevation, additional “gap water” is introduced into the system and tracked to be released in subsequent years</td></tr>
</table>

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

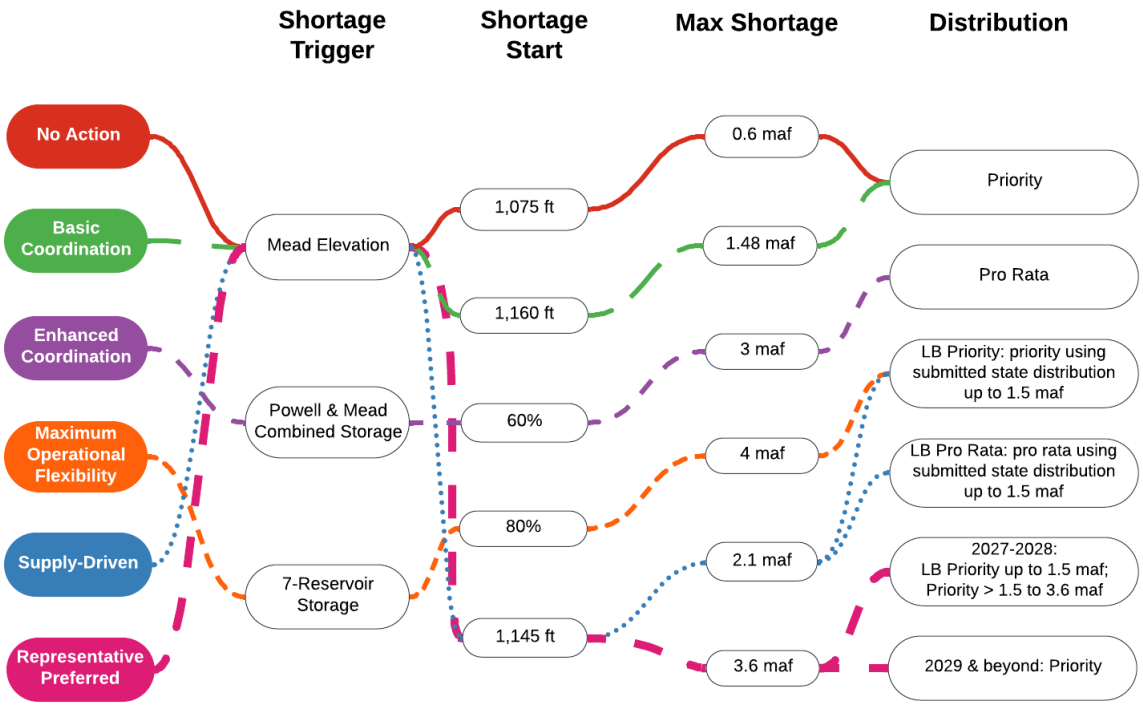
ES.2.4 Range of Alternatives

The Final EIS incorporates a reasonable and broad range of alternatives in accordance with NEPA. The figures below demonstrate the broad range of operational approaches incorporated into the alternatives by summarizing them across the following categories: Lower Basin Shortage Guidelines, Coordinated Reservoir Operations, Lake Mead Storage and Delivery of Conserved Water, and Activities above Lake Powell. For each figure below, the individual lines connect each alternative with the approach(es) that Reclamation has analyzed within that alternative.

ES.2.4.1 Lower Basin Shortage Guidelines

Figure ES-1, Lower Basin Shortage Guidelines, shows the range of approaches considered for factors that would trigger Lower Basin shortage, the level at which shortages would start, the maximum Lower Basin shortage amount, and the method(s) by which shortages would be distributed among Lower Basin water users.

Figure ES-1
Lower Basin Shortage Guidelines

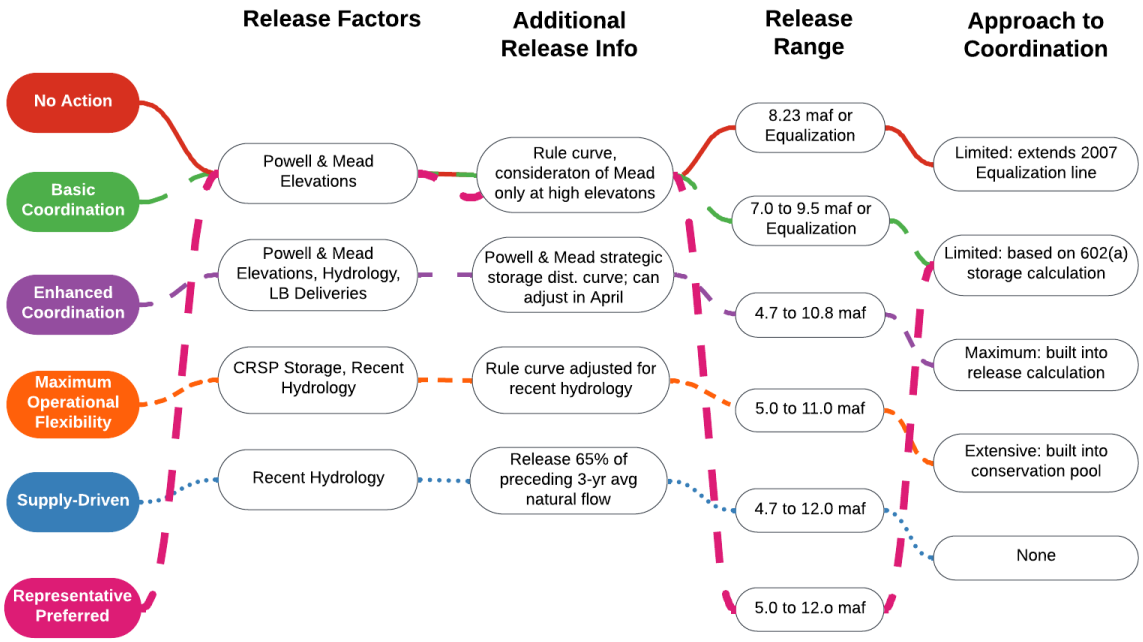


Notes: Additional restrictions in water deliveries will occur when Lake Mead is near dead pool, resulting in large reductions (referred to as "dead pool-related reductions"). These are not considered an operational element of the alternatives.
The "Representative Preferred Alternative" is a set of modeling assumptions designed around the Preferred Alternative sideboards. The specific operating guidelines for each operating interval during the term of the Preferred Alternative may differ.
Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

ES.2.4.2 Coordinated Reservoir Operations

Figure ES-2, Coordinated Reservoir Operations, shows the range of approaches considered for the factors that would determine Lake Powell water year release volumes, additional information about the structure of operations, the range of water year release volumes that could occur based on those factors, and the approach to coordination of operations between Lake Powell and Lake Mead (that is, how dependent operations of Lake Powell would be on conditions at Lake Mead).

Figure ES-2
Coordinated Reservoir Operations

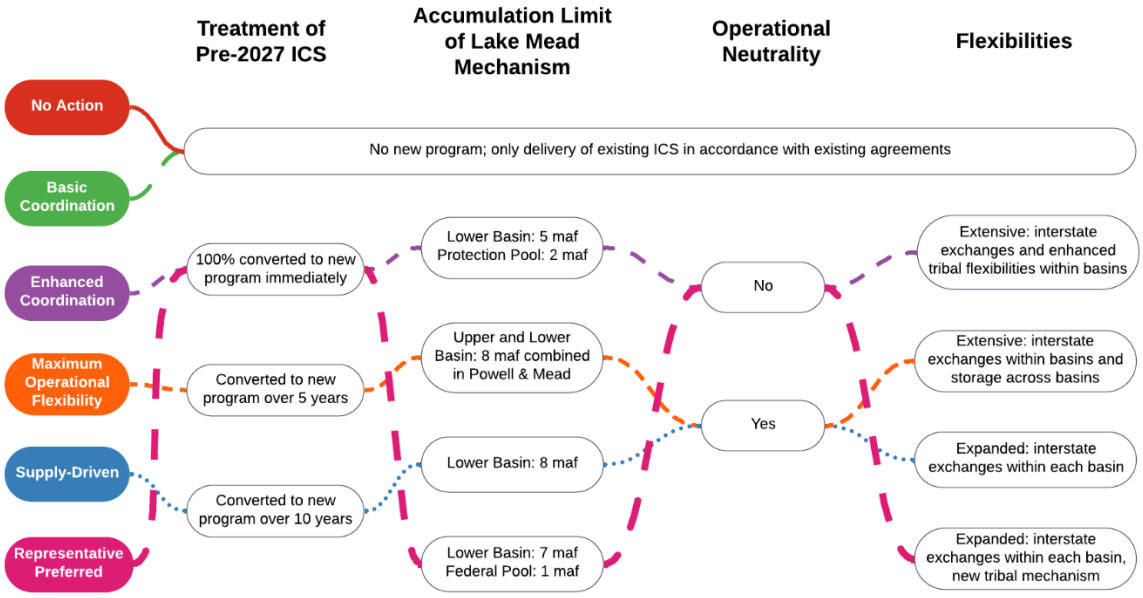


Note: The "Representative Preferred Alternative" is a set of modeling assumptions designed around the Preferred Alternative sideboards. The specific operating guidelines for each operating interval during the term of the Preferred Alternative may differ.

ES.2.4.3 Lake Mead Storage and Delivery of Conserved Water

Figure ES-3, Lake Mead Storage and Delivery of Conserved System Water, shows the range of approaches considered to incorporate this mechanism, including how Intentionally Created Surplus created prior to 2027 is converted into a new mechanism, the maximum amount of conserved water that could be stored in Lake Mead, whether stored conserved water is excluded from determinations of Lake Powell releases and shortage volumes ("operational neutrality"), and the level of flexibilities for transactions of stored conserved water between users.

Figure ES-3
Lake Mead Storage and Delivery of Conserved System Water

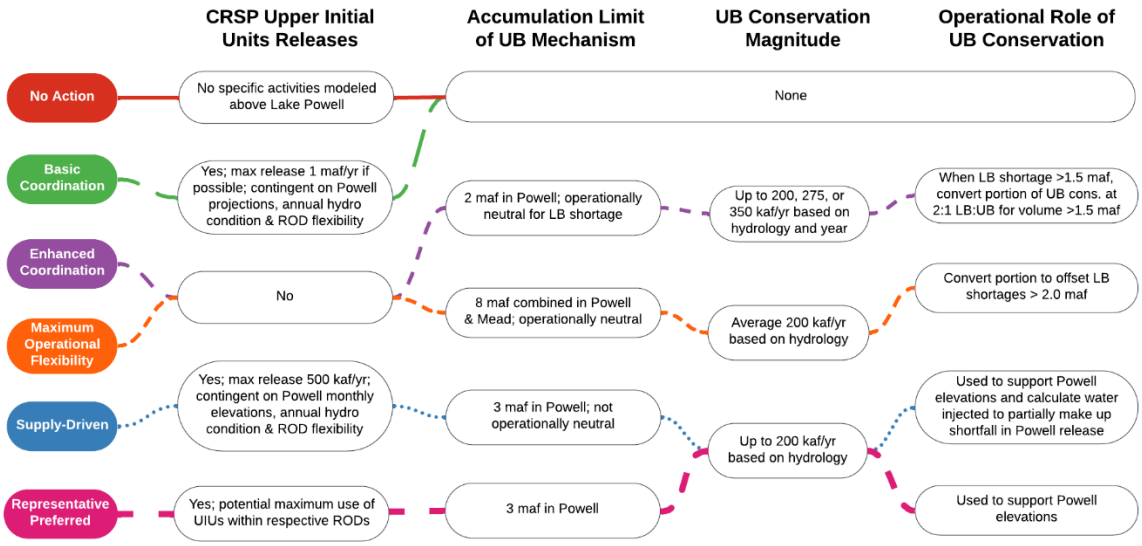


Notes: Accumulation limits include modeling assumptions for storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
The "Representative Preferred Alternative" is a set of modeling assumptions designed around the Preferred Alternative sideboards. The specific operating guidelines for each operating interval during the term of the Preferred Alternative may differ.

ES.2.4.4 Activities Above Lake Powell

Figure ES-4, Activities Above Lake Powell, shows the range of approaches to releases from CRSP Upper Initial Units to protect Glen Canyon Dam infrastructure, the maximum amount of conserved water that could be stored, assumptions about the amount of annual Upper Basin conservation, and rules for when Upper Basin conserved water would be converted to system water.

Figure ES-4
Activities Above Lake Powell



Note: The "Representative Preferred Alternative" is a set of modeling assumptions designed around the Preferred Alternative sideboards. The specific operating guidelines for each operating interval during the term of the Preferred Alternative may differ.

ES.3 Potential Environmental Effects

ES.3.1 Analysis Methods

The analysis for this Final EIS uses a Decision Making under Deep Uncertainty (DMDU) approach, drawn from a well-established branch of decision science, that is designed to account for uncertainty in future Basin conditions. The most impactful and largest source of uncertainty is future hydrology. Since 2000, hydrologic conditions drier than those in the previously observed record have continued to occur, confounding ongoing efforts to manage system risk. Reclamation began significant investments in research to improve hydrologic predictions and understanding of long-term supply outlooks in 2004, but there have been only limited improvements in prediction skill and long-term hydrologic projections continue to show a wide range of possibilities around the overall likelihood of a drier future. Therefore, long-term planning in the Basin must account for conditions of *deep uncertainty*, which occur when it is not possible to confidently assign probabilities to specific future conditions. Population growth and changes in water use in the Basin also contribute to the challenge of planning for a deeply uncertain future.

Alongside research into understanding hydrologic uncertainty, Reclamation has also invested in decision science research through the development of DMDU methods that allow for reliable analysis despite the uncertainty. Development of DMDU applications in the Basin stems from a collaboration with the RAND Corporation during the 2012 Colorado River Basin Water Supply and Demand Study, when the methods were introduced into Reclamation's long-term planning. The DMDU framework used here enhances the ability to evaluate the robustness of the alternatives – that is, their ability to meet important performance objectives in a wide range of futures. It also supports the identification of future conditions that could cause vulnerability to critical system conditions. A focus on robustness and vulnerability prevent overreliance on the types of probabilistic risk projections that, in previous planning efforts, did not convey the actual risks facing the system and contributed to insufficient protection against the ongoing drought.

The hydrologic modeling performed for this analysis employs DMDU by testing the system in 400 potential futures that cover a wide range of hydrologic conditions. This hydrologic modeling generated projections of future Colorado River system conditions (such as reservoir elevations, reservoir releases, and river flows) for the alternatives. These system projections serve as the basis for analyzing potential effects on other environmental resources (e.g., recreation, biological resources, and energy) and any associated resource specific models. For each resource, the analysis describes robustness across this wide range, identifies specific conditions that could cause vulnerability, and provides important context for interpreting those findings without overconfidently predicting system outcomes. This aligns with the guidance provided in Executive Order "Restoring Gold Standard Science" from May 2025, and provides a sound basis for comparing the alternatives' ability to meet key performance thresholds for resources throughout the Basin.

ES.3.2 Summary of Environmental Consequences

The analysis focuses on specific issues identified during internal and public scoping for all affected environmental resources (e.g., hydrologic, biologic, and socioeconomic). Resources considered but determined to not be significantly impacted by the action include transportation, noise, light, and minerals.

A summary of environmental consequences is provided in **Table ES-7**, Summary of Potential Effects of the Alternatives, located at the end of this Executive Summary. Performance indicators were developed to address the specific issues raised during scoping. Throughout, a higher percentage reflects better performance. Where quantitative or DMDU results are not possible, a qualitative description of potential impacts is provided. The affected environment and environmental consequences are discussed in detail in Chapter 3 and the associated resource appendices.

ES.4 Synthesis of Performance in Key Metrics

The action alternatives together capture a wide range of concepts across the operational elements that make up an alternative; this operational variety produces a wide range of potential system outcomes. The following sections provide an overview of performance and vulnerability over the period 2027-2036, which is significant because the Preferred Alternative is a 10-year decision framework. The Preferred Alternative, as analyzed in the Representative Preferred Alternative, is compared to the other

action alternatives, the No Action Alternative, and the Continued Current Strategies Comparative Baseline below.

ES.4.1 Performance Tradeoffs among Key System Metrics

ES.4.1.1 Introduction

Operations at Lake Powell and Lake Mead inherently involve tradeoffs among resources that benefit from different fundamental system elements: storage in each reservoir, dam releases, river flows, and water deliveries. For example, it is not possible for a set of operating guidelines to have the most robust performance with respect to maximizing protection of critical elevations, minimizing reductions in water deliveries, and maximizing hydropower generation all at once. With the extended period of dry hydrologic conditions since 2000 and the resulting depletion of storage, these tradeoffs have become more stark, and achieving a broadly acceptable balance between resources is now more difficult than ever before.

ES.4.1.2 Tradeoff Analysis

While there are many important metrics across Basin resources, it is instructive to summarize the high-level system impacts through five metrics related to Lake Powell and Lake Mead elevations, Lower Basin deliveries, and releases from Glen Canyon Dam. Analyzing tradeoffs among the metrics described in **Table ES-3** also provides important insight into the tradeoffs among other resources.

Table ES-3
High Level Performance Metrics Included in Figure ES-5

Metric Name	Description
Percent of months in which Lake Powell stays above elevation 3,500 feet	Elevation 3,500 feet provides a buffer above 3,490 feet, below which the reliability of infrastructure to meet critical downstream water supply needs may be compromised and hydropower cannot be produced at Glen Canyon Dam
Percent of months in which Lake Mead stays above elevation 975 feet	Elevation 975 feet provides a buffer above 950 feet, below which infrastructure may be critically impacted and hydropower cannot be produced at Hoover Dam
Percent of years in which Lake Mead dead pool-related reductions[5] are avoided	Delivery reductions due to Lake Mead being near dead pool (elevation 895 feet) resulting in large magnitudes of reductions to Lower Basin water users
Average annual shortage	The average annual shortage that occurs under each alternative provides important summary information for Lower Basin water users and context for reservoir-based performance
Average water year releases from Glen Canyon Dam	The average water year release from Glen Canyon Dam that occurs under each alternative provides important context for reservoir-based performance

[5] Dead pool and Hoover Dam infrastructure can start to impact Lake Mead's ability to make deliveries to the Lower Basin at elevation 950 feet. Restrictions in water deliveries will occur when Lake Mead is near dead pool, resulting in large reductions (referred to as "dead pool-related reductions"). Although not considered an operational element of the alternatives, accounting for such reductions is an important performance metric.

The elevations described in **Table ES-3** have operational relevance, and comparing alternative performance relative to these elevations provides meaningful insight. In practice, operational implementation would include identifying elevations above critical thresholds (i.e., 3,490 feet and 950 feet) at which additional responsive actions could be taken in advance to avoid reaching those critical elevations. The "buffer" elevations shown in **Table ES-3** (i.e., 3,500 feet and 975 feet) may or may not correspond to operational decision for actual implementation; here, they are used for analytical purposes in this Final EIS.

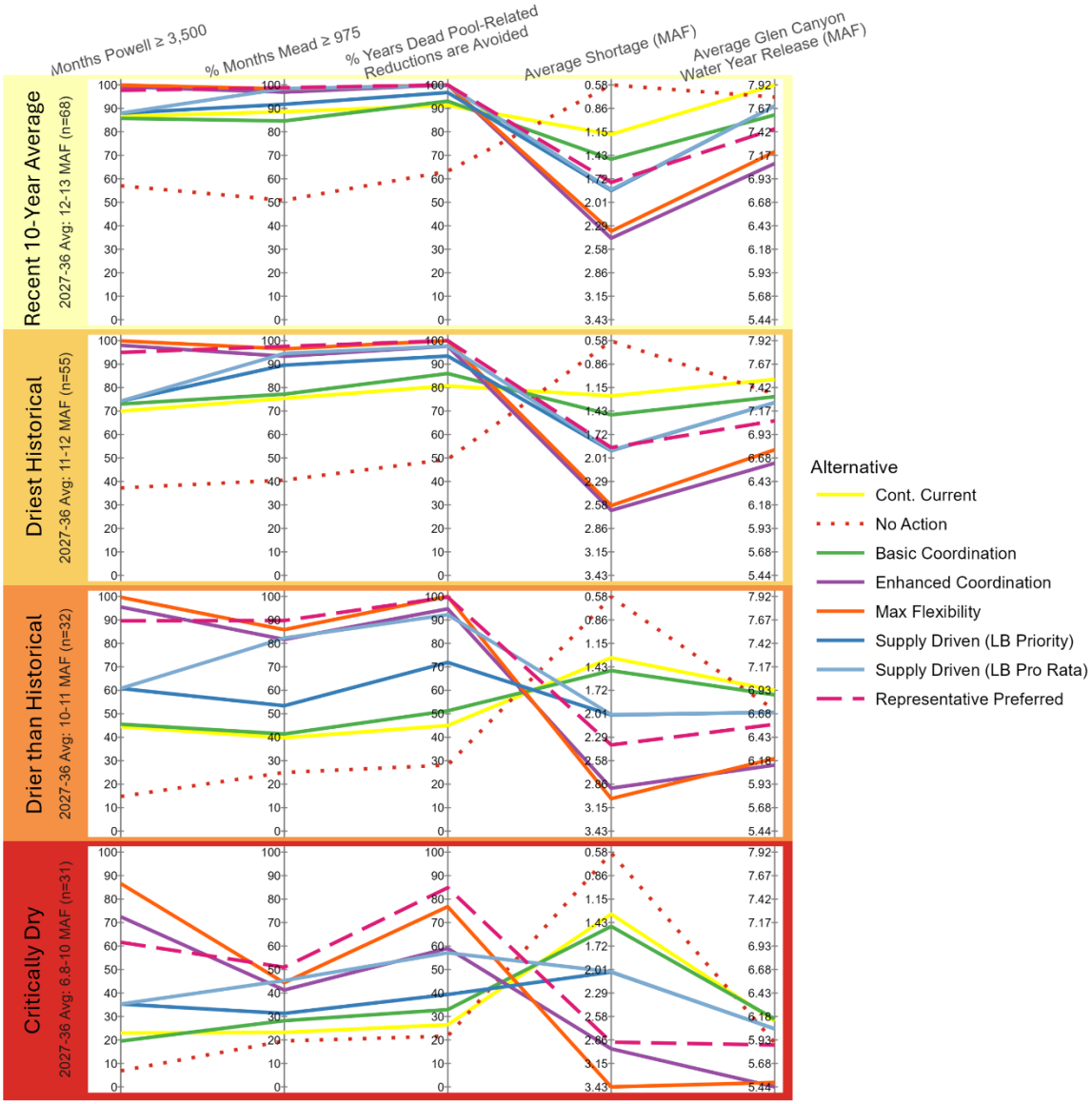
Figure ES-5 summarizes how the alternatives and the Continued Current Strategies Comparative Baseline[6] (labeled "Cont. Current") perform over the next 10 years in five vertical axes that correspond to the five key metrics described in **Table ES-3**. The performance of each alternative is captured by a colored, segmented line that crosses the axes at different vertical positions, where the height denotes performance. Crossing lines are a visual cue that there is a tradeoff between different performance metrics. The five-metric performance summary is divided into four categories of potential 2027-2036 future hydrologic conditions that get increasingly dry from top to bottom.[7] The hydrologic categories are summarized in **Table ES-4**. Results are divided into these categories to demonstrate how the alternatives respond under different assumptions about future hydrologic conditions and to explore the impacts of hydrology on performance tradeoffs.

Table ES-4
Hydrologic Categories Included in Figure ES-5

Hydrologic Category	Average Annual Simulated Lees Ferry Flow, 2027-2036 (maf)	Description
Recent 10-Year Average	12-13	Hydrologic conditions in this category are similar to the historical average from 2016-2025 (12.1 maf)[8]
Driest Historical	11-12	Hydrologic conditions in this category are similar to the driest 10-year period in the historical record (11.8 maf, 2012-2021)
Drier than Historical	10-11	Hydrologic conditions in this category are 7-15% (0.8 to 1.8 maf) drier than the driest 10-year period in the historical record
Critically Dry	<10	Hydrologic conditions in this category are 15-42% (1.8-5.0 maf) drier than the driest 10-year period in the historical record

[6] This scenario represents no changes from current operations and relies on strategies and agreements that expire in 2026. It is provided as a comparative baseline to inform an understanding of how the alternatives perform relative to current operations.
[7] Wetter futures were also tested and are included in the impact analysis; however, for this analysis the hydrologic categories shown are most informative.
[8] The 10-year average for 2014-2023 (12.8 maf), 2015-2024 (12.6 maf), and 2016-2025 (12.1 maf) are all between 12 and 13 maf.

Figure ES-5
Key Performance Tradeoffs in Different Hydrologic Conditions



Note: Differences in Lake Mead performance between Supply Driven (Lower Basin [LB] Priority) and the Supply Driven (LB Pro Rata) Alternatives reflect how different shortage distributions interact with assumptions regarding the use of the storage and delivery mechanism for conserved water.

A key performance tradeoff demonstrated by **Figure ES-5** is the tradeoff between percent of time in which critical reservoir elevations and dead pool-related reductions are avoided (first three axes from left) and average shortage (fourth axis from left). In the Recent 10-Year Average hydrologic category, this stands out as a difference between the No Action Alternative and the action alternatives, but in the drier hydrologic categories (especially Drier than Historical and Critically Dry), the performance differences between the action alternatives becomes clearer and the tradeoffs (indicated by the crossing lines) become steeper: the Maximum Operational Flexibility and Enhanced Coordination Alternatives incorporate large shortages and better protect the reservoirs, the Supply Driven Alternatives and the Basic Coordination Alternative have lower volumes of shortage and lower reservoir protection, and the No Action Alternative provides minimal protection and results in a high frequency of dead pool-related reductions while imposing minimal shortage. Across hydrologic categories, the Representative Preferred Alternative balances tradeoffs differently than other action alternatives. This is evident beginning in the Driest Historical hydrologic category, where it provides protection of Lake Powell and Lake Mead elevations similar to the most protective alternatives, while the average shortage volumes are similar to the Supply Driven Alternatives.

In Drier than Historical hydrologic futures, the Maximum Operational Flexibility and Enhanced Coordination Alternatives show that lower water year releases from Glen Canyon Dam provide more protection to keep Lake Powell above 3,500 feet, while the higher water year releases in Basic Coordination and Supply Driven result in significantly higher frequencies of Lake Powell falling below 3,500 feet. The Representative Preferred Alternative falls in between Supply Driven and Enhanced Coordination Alternatives: it releases less from Glen Canyon on average than the Supply Driven Alternative and better protects elevation 3,500 feet, but it releases more and offers less protection compared to the Enhanced Coordination Alternative. In the Critically Dry hydrologic category, water year releases are low across all alternatives, but only the Representative Preferred (62 percent of months), Enhanced Coordination (72 percent of months) and Maximum Operational Flexibility (87 percent of months) Alternatives protect 3,500 feet more than half of the time. The Supply Driven Alternatives and Basic Coordination Alternative maintain elevations above 3,500 feet in 35 percent and 20 percent of months, respectively.

The effectiveness of large shortages at preventing dead pool-related delivery reductions is clearest in the Critically Dry hydrologic category, where the Representative Preferred, Maximum Operational Flexibility, and Enhanced Coordination Alternatives rely on large average shortages to significantly outperform the other alternatives in avoiding dead pool-related reductions. However, in Critically Dry conditions, even these more protective alternatives result in Lake Mead elevations below 975 feet in 49, 56, and 59 percent of months, respectively.

Figure ES-1 is a quantitative representation of system tradeoffs and shows how those tradeoffs are exacerbated by drying hydrologic conditions. The analysis in this figure demonstrates how the sideboards of the Preferred Alternative, as analyzed in the Representative Preferred Alternative, appropriately balance the tradeoffs across key system metrics and provide protection in conditions drier than the ongoing, unprecedented drought. The Representative Preferred Alternative achieves good performance across key system metrics related to critical infrastructure in the driest hydrologic conditions the Basin has experienced (Driest Historical Hydrology) but imposes lower average shortages and enables higher Glen Canyon Dam releases than other similarly protective alternatives. In

conditions that are slightly drier than observed history (Drier than Historical Hydrology), the Representative Preferred Alternative maintains this moderate balance of performance between reservoir elevations, shortages, and Glen Canyon Dam releases. In the driest hydrologic conditions modeled (Critically Dry Hydrology), the ability of any set of operations to achieve good performance in these metrics is significantly diminished, but the Representative Preferred Alternative shows that the Preferred Alternative sideboards can protect critical infrastructure in the majority of these conditions while considering adverse impacts to Lower Basin water users.

ES.4.2 Vulnerability Analysis for Key Reservoir Elevations

The analysis related to **Figure ES-5** examines tradeoffs and the influence of different hydrologic scenarios on the alternatives' performance in important metrics. **Table ES-5** and **Table ES-6**, below, provide insight into what specific hydrology is likely to cause the system to be vulnerable to critical conditions under different alternatives and whether those conditions are similar to anything from the observed record. This context is helpful in understanding whether the conditions leading to vulnerability could be reasonably expected based on history.[9] Based on analysis of 400 modeled hydrologic futures, an average-flow threshold was identified for each alternative that skillfully predicted the occurrence of a critical system condition at least once within 10 years of implementation (between 2027 and 2036).

Table ES-5
Vulnerability to Lake Powell Falling Below Elevation 3,500 Feet at Least Once in the First 10 Years and Comparison to Historical Conditions

Alternative	Water Year 2027-2036 Average Natural Flow that Could Cause Vulnerability (maf/year)	Number of Years Below Threshold 2000-2025 (Historical Data)	Number of Years Below Threshold 1906-2025 (Historical Data)
Cont. Current	≤12.1	3	4
No Action	≤19.6	26	111
Basic Coordination	≤11.9	1	1
Enhanced Coordination	≤9.3	0	0
Max Flexibility	≤8.1	0	0
Supply Driven (LB Priority)	≤12.5	7	9
Supply Driven (LB Pro Rata)	≤12.5	7	9
Representative Preferred	≤10.1	0	0

[9] Information about how the vulnerability thresholds compare to projections of future conditions, which include the potential for a drier future, can be found in **Technical Appendix 3**, Hydrologic Resources.

Table ES-6
Vulnerability to Lake Mead Falling Below Elevation 975 Feet at Least Once in the First 10 Years and Comparison to Historical Conditions

Alternative	Water Year 2027-2036 Average Natural Flow that Could Cause Vulnerability (maf/year)	Number of Years Below Threshold 2000-2025 (Historical Data)	Number of Years Below Threshold 1906-2025 (Historical Data)
Cont. Current	≤11.6	0	0
No Action	≤14.5	23	67
Basic Coordination	≤11.3	0	0
Enhanced Coordination	≤9.7	0	0
Max Flexibility	≤10.0	0	0
Supply Driven (LB Priority)	≤11.1	0	0
Supply Driven (LB Pro Rata)	≤9.7	0	0
Representative Preferred	≤10.0	0	0

With respect to Lake Powell falling below elevation 3,500 feet at least once in the next 10 years, the Supply Driven Alternative is the most vulnerable action alternative: under these operations, Lake Powell would likely fall to critical elevations if the 10-year average natural flow at Lees Ferry is 12.5 maf or lower. Hydrologic conditions this dry or drier occurred in 7 years since 2000. With respect to Lake Mead falling below elevation 975 feet at least once in the next 10 years, the flow thresholds indicating vulnerability are drier for all of the action alternatives than any observed historical conditions. However, conditions this dry do occur in the set of 400 hydrologic traces analyzed in this EIS, which includes the potential for a future drier than historical observations (see **Appendix F**, Approach to Hydrologic Uncertainty, for information about the 400 hydrologic traces).

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Powell falling below 3,500 feet if the 2027-2026 average flow is 10.1 maf or less and Lake Mead falling below 975 feet if the 2027-2036 average flow is 10.0 maf or less. The Representative Preferred Alternative is reasonably unlikely to be vulnerable in the next 10 years because these conditions have not occurred and are about 15 percent drier than the driest 10-year period on record (2012-2021, average of 11.8 maf). However, estimates for 2026 natural flow suggest 2017-2026 will become the driest 10-year period on record (about 11.5 maf), reflecting that hydrology could continue to decline relative to the comparisons in this table. The possibility for a drier future is reflected in the set of 400 hydrologic traces analyzed in this EIS.

ES.4.3 Conclusions

A number of reservoir and water management decisional documents and agreements that govern operation of Colorado River facilities and management of Colorado River water are currently scheduled to expire at the end of 2026. The Secretary, acting through Reclamation, proposes adoption of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating range, to be implemented upon the expiration of the existing guidelines and agreements. Management strategies will primarily focus on the operation of Glen Canyon Dam and Hoover Dam but may include actions upstream and downstream of these facilities to protect critical reservoir elevations.

Since the adoption of the current guidelines in 2007, unprecedented drought has changed the Basin's understanding of hydrology. Hydrologic conditions drier than those in the previously observed record have continued to occur, confounding ongoing efforts to manage system risk. This reality poses both near- and long-term challenges in managing the Colorado River system to continue to provide predictability and certainty to Basin water users as well as operating flexibility to conserve and enhance water storage in Colorado River system reservoirs.

This Final EIS analyzes a reasonable and broad range of alternatives for the operational elements identified in the proposed federal action. These alternatives were developed through extensive engagement with a wide range of partners and stakeholders as well as the general public during a timeframe of over 4 years. In the absence of a consensus long-term agreement, Reclamation has included a Preferred Alternative decision framework in this Final EIS that establishes the operational principles, sideboards, and process that would govern development and adoption of operating guidelines through 2036. The sideboards of the Preferred Alternative were analyzed through the Representative Preferred Alternative, and the analysis of the potential impacts of these sideboards provides environmental compliance for decisions made consistent with the decision framework. Based on the analysis in this Final EIS and the key tradeoffs shown above, the Preferred Alternative, as analyzed in the Representative Preferred Alternative, appropriately balances the inherent system tradeoffs: it is a practical approach to robust protection of critical infrastructure while considering adverse impacts to water users and avoiding unnecessary impacts to other resources.

ES.5 Summary of Potential Effects

Table ES-7
Summary of Potential Effects of the Alternatives

Hydrology (See Section 3.3)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir Elevations	Ranking of alternatives related to Lake Powell end of water year (EOWY) median elevations in the critically dry flow category.	**Ranked #6.** Lowest median elevations in the critcally dry flow category.	**Ranked #5**. Second lowest median elevations in the critcally dry flow category.	**Ranked #1.** Highest median elevations in the critcally dry flow category.	**Ranked #2.** Second highest median elevations in the critcally dry flow category.	**Tied Ranked #4.** Tied third lowest median elevations in the critcally dry flow category (same as Supply Driven Alternative [LB Pro Rata approach]).	**Tied Ranked #4.** Tied third lowest median elevations in the critcally dry flow category (same as Supply Driven Alternative [LB Priority approach]).	**Ranked #3.** Third highest median elevations in the critcally dry flow category.
	Percent of modeled futures in which *Lake Powell elevation stays above 3,500 feet 100% of the time*. The higher the percentage, the more likely Lake Powell will remain above the minimum power pool (3,490 feet) under most future hydrologic scenarios.	**4%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**19%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**81%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**94%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**35%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**35%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**58%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
	Ranking of alternatives related to Lake Mead end of calendar year (EOCY) median elevations in the critically dry flow category.	**Ranked #7.** Lowest median elevations in the critcally dry flow category.	**Ranked #6.** Second lowest median elevations in the critcally dry flow category.	**Ranked #4.** Fourth lowest median elevations in the critcally dry flow category.	**Ranked #2**. Second highest median elevations in the critcally dry flow category.	**Ranked #3**. Third highest median elevations in the critcally dry flow category.	**Ranked #1**. Highest median elevations in the critcally dry flow category.	**Ranked #5.** Third lowest median elevations in the critcally dry flow category.
	Percent of futures in which *Lake Mead elevation stays above 975 feet 100% of the time*. The higher the percentage, the more likely Lake Mead will remain above the minimum power pool (950 feet) under most future hydrologic scenarios.	**32%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**62%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**74%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**77%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**69%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**81%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**72%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir Elevations *(continued)*	Lake Mohave and Lake Havasu end of year elevations.	No impact; the existing rule curves continue to determine elevations.						
System Storage	Ranking of alternatives related to Lake Powell + Lake Mead combined median storage capacity in all flow categories.	**Ranked #7.** Lowest combined storage in all flow categories.	**Ranked #6.** Second lowest combined storage in all flow categories.	**Ranked #1.** Highest combined storage in all flow categories.	**Ranked #2.** Second highest combined storage in all flow categories.	**Ranked #5.** Third lowest combined storage in all flow categories.	**Ranked #3.** Third highest combined storage in all flow categories.	**Ranked #4.** Fourth highest combined storage in all flow categories.
	Ranking of alternatives related to CRSP Reservoir (Flaming Gorge, Navajo, Blue Mesa, and Powell) combined median storage capacity in the two driest flow categories.	**Tied Ranked #4.** Tied second lowest combined storage in the driest flow categories (same as both Supply Driven Alternatives).	**Ranked #5.** Lowest combined storage in the driest flow categories.	**Ranked #1.** Highest combined storage in the driest flow categories.	**Ranked #2.** Second highest combined storage in the driest flow categories.	**Tied Ranked #4.** Tied second lowest combined storage in the driest flow categories. (same as Supply Driven Alternative [LB Pro Rata approach] and No Action).	**Tied Ranked #4.** Tied second lowest combined storage in the driest flow categories. (same as Supply Driven Alternative [LB Priority approach] and No Action).	**Ranked #3.** Third highest combined storage in the driest flow categories.
	Ranking of alternatives related to Seven-Reservoir (Flaming Gorge, Navajo, Blue Mesa, Powell, Mead, Mohave, and Havasu) combined median storage capacity in all flow categories.	**Ranked #7.** Lowest combined storage in all flow categories.	**Ranked #6.** Second lowest combined storage in all flow categories.	**Ranked #1.** Highest combined storage in the driest flow categories.	**Ranked #2.** Second highest combined storage in all flow categories	**Ranked #4.** Fourth highest combined storage in all flow categories	**Ranked #3.** Third highest combined storage in all flow categories.	**Ranked #5.** Third lowest combined storage in all flow categories.
Reservoir Releases	Annual Glen Canyon Dam EOWY releases under average and critically dry hydrology conditions (median values)	Releases of 8.23 maf in the average flow category. Releases of 6.36 maf the critically dry flow category.	Releases of 8.23 maf in the average flow category. Releases of 6.92 maf in the critically dry flow category.	Releases of 7.95 maf in the average flow category. Releases of 5.11 maf in the critically dry flow category.	Releases of 8.17 maf in the average flow category. Releases of 5.61 maf in the critically dry flow category.	Releases of 8.41 maf in the average flow category. Releases of 6.04 maf in the critically dry flow category.	Releases of 8.41 maf in the average flow category. Releases of 6.04 maf in the critically dry flow category.	Releases of 8.23 maf in the average flow category. Releases of 6.00 maf in the critically dry flow category.
	10-year Glen Canyon Dam releases under average and critically dry hydrology conditions (median values)	Releases of 80.8 maf in the average flow category. Releases of 74.3 maf Releases in the critically dry flow category.	Releases of 79.0 maf in the average flow category. Releases of 74.5 maf in the critically dry flow category.	Releases of 77.4 maf in the average flow category. Releases of 69.1 maf in the critically dry flow category.	Releases of 78.9 maf in the average flow category. Releases of 70.8 maf in the critically dry flow category.	Releases of 81.7 maf in the average flow category. Releases of 73.5 maf in the critically dry flow category.	Releases of 81.7 maf in the average flow category. Releases of 73.5 maf in the critically dry flow category.	Releases of 78.8 maf in the average flow category. Releases of 72.5 maf in the critically dry flow category.
	10-year Lee Ferry Compact Point flow volumes under average and critically dry hydrology conditions (median values)	Flows of 82.3 maf in the average flow category. Flows of 75.7 maf in the critically dry flow category.	Flows of 80.6 maf in the average flow category. Flows of 76.0 maf in the critically dry flow category.	Flows of 78.9 maf in the average flow category. Flows of 70.6 maf in the critically dry flow category.	Flows of 80.6 maf in the average flow category. Flows of 72.4 maf in the critically dry flow category.	Flows of 83.4 maf in the average flow category. Flows of 74.9 maf in the critically dry flow category.	Flows of 83.4 maf in the average flow category. Flows of 74.9 maf in the critically dry flow category.	Flows of 80.4 maf in the average flow category. Flows of 73.9 maf in the critically dry flow category

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir Releases *(continued)*	Annual EOCY Hoover Dam releases under critically dry hydrology conditions (median values)	Releases of 8.7 maf in the average flow category. Flows of 7.2 maf in the critically dry flow category.	Releases of 8.0 maf in the average flow category. Flows of 7.7 maf in the critically dry flow category.	Releases of 7.6 maf in the average flow category. Flows of 6.5 maf in the critically dry flow category.	Releases of 7.8 maf in the average flow category. Flows of 6.4 maf in the critically dry flow category.	Releases of 7.7 maf in the average flow category. Flows of 7.2 maf in the critically dry flow category.	Releases of 7.7 maf in the average flow category. Flows of 7.1 maf in the critically dry flow category.	Releases of 7.9 maf in the average flow category. Flows of 6.9 maf in the critically dry flow category.
	Annual EOCY Davis Dam releases under average and critically dry hydrology conditions (median values)	Releases of 8.5 maf in the average flow category. Releases of 7.1 maf in the critically dry flow category.	Releases of 7.9 maf in the average flow category. Releases of 7.6 maf in the critically dry flow category.	Releases of 7.4 maf in the average flow category. Releases of 6.4 maf in the critically dry flow category.	Releases of 7.6 maf in the average flow category. Releases of 6.3 maf in the critically dry flow category.	Releases of 7.6 maf in the average flow category. Releases of 7.1 maf in the critically dry flow category.	Releases of 7.5 maf in the average flow category. Releases of 7.0 maf in the critically dry flow category.	Releases of 7.8 maf in the average flow category. Releases of 6.9 maf in the critically dry flow category.
	Annual EOCY Parker Dam releases under average and critically dry hydrology conditions (median values)	Releases of 6.6 maf in the average flow category. Releases of 6.0 maf in the critically dry flow category.	Releases of 6.5 maf in the average flow category. Releases of 6.3 maf in the critically dry flow category.	Releases of 5.5 maf in the average flow category. Releases of 4.6 maf in the critically dry flow category.	Releases of 6.3 maf in the average flow category. Releases of 5.7 maf in the critically dry flow category.	Releases of 6.3 maf in the average flow category. Releases of 6.1 maf in the critically dry flow category.	Releases of 5.8 maf in the average flow category. Releases of 5.4 maf in the critically dry flow category.	Releases of 6.4 maf in the average flow category. Releases of 5.9 maf in the critically dry flow category.
	Ranking of alternatives related to median river flows in Reach 1 (Glen Canyon Dam to Lake Mead).	**Ranked #2.** Second highest median river flows in the critically dry flow category. Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Ranked #1.** Highest median river flows in the critically dry flow category. Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Ranked #6.** Lowest median river flows in the critically dry flow category. Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Ranked #5.** Second lowest median river flows in the critically dry flow category. Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Tied Ranked #3.** Tied third highest median river flows in the critically dry flow category (same as Supply Driven Alternative [LB Pro Rata]). Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Tied Ranked #3.** Tied third median river flows in the critically dry flow category (same as Supply Driven Alternative [LB Priority]). Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.	**Ranked #4.** Third lowest median river flows in the critically dry flow category (same as No Action Alternative). Mirrors trends for releases from Glen Canyon Dam. River flows decrease as flow categories get drier.
River Flows	Ranking of alternatives related to median river flows in Reach 2 (Hoover Dam to Lake Mohave)	**Ranked #3.** Third highest median river flows in the critically dry flow category. Mirrors trends for distributes from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #1.** Highest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #6.** Second lowest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #7**. Lowest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #2.** Second highest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #4.** Fourth highest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.	**Ranked #5.** Third lowest median river flows in the critically dry flow category. Mirrors trends for releases from Hoover Dam. River flows decrease as flow categories get drier.
	Ranking of alternatives related to median river flows in Reach 3 (Davis Dam to Lake Havasu)	**Tied Ranked #2**. Tied second highest median river flows in the critically dry flow category (same as the Supply Driven Alternative [LB Priority]). Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Ranked #1.** Highest median river flows in the critically dry flow category. Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Ranked #5**. Second lowest median river flows in the critically dry flow category. Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Ranked #6**. Lowest median river flows in the critically dry flow category. Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Tied Ranked #2**. Tied second highest median river flows in the critically dry flow category (same as No Action Alternative). Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Ranked #3**. Third highest median river flows in the critically dry flow category. Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.	**Ranked #4**. Third lowest median river flows in the critically dry flow category. Mirrors trends for releases from Davis Dam. River flows decrease as flow categories get drier.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
River Flows *(continued)*	Ranking of alternatives related to median river flows in Reach 4 (Parker Dam to Cibola Gage)	**Ranked #3**. Third highest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #1.** Highest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #7**. Lowest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #5**. Third lowest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #2**. Second highest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #6**. Second lowest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.	**Ranked #4**. Fourth highest median river flows in the critically dry flow category. Mirrors trends for releases from Parker Dam. River flows decrease as flow categories get drier.
	Ranking of alternatives related to median river flows in Reach 5 (Cibola Gage to Imperial Dam)	**Ranked #3**. Third highest median river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #1.** Highest median river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #7**. Lowest median flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #5**. Third lowest median river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #2**. Second highest river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #6**. Second lowest median river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.	**Ranked #4**. Fourth highest river flows in the critically dry flow category. Mirrors trends for river flows in Reach 4. River flows decrease as flow categories get drier.
	Ranking of alternatives related to median river flows in Reach 6 (Imperial Dam to Northerly International Boundary [NIB])	**Tied Ranked #3**. Tied third highest median river flows in critically dry flow category (same as Representative Preferred Alternative). Releases of 0.9 maf in the critically dry flow category.	**Ranked #1**. Highest river flows in critically dry flow category. Releases of 1.0 maf in the critically dry flow category.	**Ranked #6**. Lowest median river flows in critically dry flow category. Releases of 0.8 maf in the average flow category.	**Ranked #4**. Third lowest median river flows in critically dry flow categories. Releases of 0.8 maf in the critically dry flow category.	**Ranked #2**. Second highest river flows in critically dry flow category. Releases of 0.9 maf in the critically dry flow category.	**Ranked #5.** Second lowest median river flows in critically dry flow category. Releases of 1.0 maf in the critically dry flow category.	**Tied Ranked #3**. Tied third highest median river flows in all flow categories (same as No Action Alternative). Releases of 0.8 maf in the critically dry flow category.
	Likelihood for infrequent river flows to occur in wetter flow categories in Reach 7 (NIB to SIB, below Morelos)	Flows below Morelos Dam are infrequent under all flow categories. **Least likely** for infrequent flows to occur in the wetter flow categories.	Flows below Morelos Dam are infrequent under all flow categories. **Least likely** for infrequent flows to occur in the wetter flow categories.	Flows below Morelos Dam are infrequent under all flow categories. **Among the middle performing** for infrequent flows to occur in the wetter flow categories.	Flows below Morelos Dam are infrequent under all flow categories. **Among the middle performing** for infrequent flows to occur in the wetter flow categories.	Flows below Morelos Dam are infrequent under all flow categories. **Most likely** for infrequent flows to occur in the wet flow category.	Flows below Morelos Dam are infrequent under all flow categories. **Most likely** for infrequent flows to occur in the wet flow category.	Flows below Morelos Dam are infrequent under all flow categories. **Among the middle performing** for infrequent flows to occur in the wetter flow categories.
Groundwater	Groundwater in Reach 1 (Glen Canyon Dam to Lake Mead).	**Ranked #6**. Least robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Ranked #5**. Second least robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Ranked #2**. Second most robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Ranked #1**. Most robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Tied Ranked #3**. Tied third most robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Tied Ranked #3**. Tied third most robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.	**Ranked #4**. Third least robust at keeping elevations at Lake Powell above 3,500 feet; changes to groundwater levels adjacent to Lake Powell may be affected by changes in reservoir elevations. Groundwater elevations through Grand Canyon are not anticipated to be affected.
	Groundwater in Reach 2 (Hoover Dam to Lake Mohave)	Groundwater elevations through this reach are not anticipated to be affected.						

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Groundwater *(continued)*	Groundwater in Reach 3 (Davis Dam to Lake Havasu)	**Tied Ranked #2.** Tied second highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Ranked #1**. Highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Ranked #5**. Second lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Ranked #6**. Lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Tied Ranked #2**. Tied second highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Ranked #3**. Third highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.	**Ranked #4**. Third lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage. Groundwater elevations adjacent to Lake Havasu are not anticipated to be affected.
	Groundwater in Reach 4 (Parker Dam to Cibola Gage)	**Ranked #3**. Third highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #1.** Highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #7.** Lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #5.** Third lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #2.** Second highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #6**. Second lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #4.** Fourth highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.
	Groundwater in Reach 5 (Cibola Gage to Imperial Dam)	**Ranked #3.** Third highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #1.** Highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #7.** Lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #5.** Third lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #2.** Second highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #6.** Second lowest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.	**Ranked #4.** Fourth highest river flows in reach; changes to groundwater levels adjacent to the river may be affected by changes in river stage.
	Groundwater in Reach 6 (Imperial Dam to NIB)	Most of the river channel is bypassed with a series of canals and sluiceways. Groundwater elevations through this reach are not anticipated to be affected.						
	Groundwater in Reach 7 (NIB to SIB)	**Least likely** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Least likely** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Among the middle performing** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Among the middle performing** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Most likely** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Most likely** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.	**Among the middle performing** for infrequent flows to occur in this reach. Groundwater in the southern reach of the limitrophe may be affected by decreased flows.

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Water Deliveries (See Section 3.4)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Apportionments	Upper Division States	No impact	No impact	No impact	No impact	No impact	No impact	No impact
	Lower Division States	Shortages are distributed based on priority.	Shortages are distributed based on priority.	Shortages are distributed based on pro rata.	Shortages are distributed priority based on Lower Division States' submission.	Shortages are distributed priority based on Lower DivisionD States' submission.	Shortages are distributed pro rata based on Lower DivisionD States' submission.	Shortages are distributed based on priority.
Lower Division States Water Supply Determinations and Total Water Deliveries[2]	Percent of modeled futures in which *dead pool-related reductions are avoided in 100% of years*. The higher the percentage, the more likely dead pool-related reductions are avoided.	**41%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**68%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**88%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**94%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**77%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**88%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**95%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
	Effects of modeling assumptions for Upper and Lower Basin conservation activity (comparison of shortage and depletion results when turning conservation activity on and off).	Median reductions remain **similar** with conservation on or off.[3]	Median reductions remain **similar** with conservation on or off.[1]	Median shortages **slightly higher with conservation off** compared to conservation on in all flow categories. Median depletions **slightly lower with conservation off** in all flow categories.	Median shortages **slightly lower with conservation off** compared to conservation on in **wetter flow** categories **but higher or similar** in **drier flow** categories. Median depletions **slightly higher with** conservation **off** compared to conservation on in **wetter flow categories but slightly lower in drier flow categories**.	Median shortages **slightly lower with conservation off** compared to conservation on. Median depletions **slightly higher with conservation off** compared to conservation on.	Median shortages **slightly lower with conservation off** compared to conservation on. Median depletions **slightly higher with conservation off** compared to conservation on.	Median shortages **higher with conservation off** compared to conservation on. Median depletions **slightly lower with conservation off** compared to conservation on.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[2] Total shortage volumes and deliveries include assumptions related to reductions in water deliveries to Mexico. Appendix A provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[3] While the No Action and Basic Coordination alternatives do not include mechanisms to conserve and store water in Lake Powell or Lake Mead, the model does include assumptions for the delivery of existing ICS that was conserved prior to 2027. In the conservation-off results, activity related to pre-2027 conservation is turned off for all the alternatives and the CCS Comparative Baseline. Refer to TA 4, Water Deliveries, for more details.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	**Basic Coordination Alternative**	**Enhanced Coordination Alternative**	**Maximum Operational Flexibility Alternative**	**Supply Driven Alternative (LB Priority)**	**Supply Driven Alternative (LB Pro Rata)**	**Representative Preferred Alternative**
Lower Division States Water Supply Determinations and Total Water Deliveries *(continued)*	Maximum shortage (maf) where shortage is any modeled reduction to the ability of an entitlement holder to exercise an entitlement as described in the assumptions of the model	Total Lower Basin: 0.60[4] Arizona: 0.47 California: 0.00 Nevada: 0.03	Total Lower Basin: 1.48[4] Arizona: 1.15 California: 0.00 Nevada: 0.08	Total Lower Basin: 3.00 Arizona: 0.93 California: 1.47 Nevada: 0.10	Total Lower Basin: 4.00 Arizona: 1.93 California: 1.28 Nevada: 0.20	Total Lower Basin: 2.10 Arizona: 1.22 California: 0.44 Nevada: 0.09	Total Lower Basin: 2.10 Arizona: 0.92 California: 0.76 Nevada: 0.07	Total Lower Basin: 3.6 Arizona: 1.96 California: 0.9 Nevada: 0.21
	Annual volume of Lower Basin shortage and dead pool-related reductions under critically dry hydrologic conditions (median values). Volumes are expressed as a total volume of reductions to the Lower Basin, including Mexico.	Median reductions increase as flow categories become drier. Shortage: 0.6 maf **Lowest** Dead pool-related reductions: 1.5 maf **Highest**	Median reductions increase as flow categories become drier. Shortage: 1.5 maf **Second lowest** Dead pool-related reductions: 0 maf **Tied lowest**	Median reductions increase as flow categories become drier. Shortage: 3.0 maf **Second highest** Dead pool-related reductions: 0 maf **Tied lowest**	Median reductions increase as flow categories become drier. Shortage: 3.1 maf **Highest** Dead pool-related reductions: 0 maf **Tied lowest**	Median reductions increase as flow categories become drier. Shortage: 2.0 maf **Third lowest** Dead pool-related reductions: 0 maf **Tied lowest**	Median reductions increase as flow categories become drier. Shortage: 1.9 maf **Third lowest** Dead pool-related reductions: 0 maf **Tied lowest**	Median reductions increase as flow categories become drier. Shortage: 2.1 maf **Third highest** Dead pool-related reductions: 0 maf **Tied lowest**
	Annual shortage by state under critically dry hydrology conditions (median values). Values are reported as percent of apportionment.	Arizona: 16.7%[4] **Lowest** California: 0% **Lowest** Nevada: 11% **Lowest**	Arizona: 41.1%[4] **Fourth highest** California: 0% **Lowest** Nevada: 27.2% **Fourth highest**	Arizona: 33.3% **Third lowest** California: 33.3% **Highest** Nevada: 33.3% **Third highest**	Arizona: 58.7% **Highest** California: 17.3% **Second highest** Nevada: 48.0% **Highest**	Arizona: 41.2% **Third highest** California: 10.0% **Second lowest** Nevada: 26.6% **Third lowest**	Arizona: 31.8% **Second lowest** California: 15.8% **Third lowest** Nevada: 22.0% **Second lowest**	Arizona: 53.1% **Second highest** California: 10.0% **Second lowest** Nevada: 36.3% **Second highest**
	Annual depletions (reported as percent of apportionment) by state under critically dry hydrology conditions (median values). Depletion is defined as total consumptive use (such as the amount of water diverted from the river) minus the return flow.	Arizona: 56.7% **Third lowest** California: 90.9% **Second highest** Nevada: 66.8% **Lowest**	Arizona: 58.9% **Second highest** California: 100% **Highest** Nevada: 83.3% **Second highest**	Arizona: 67.5% **Highest** California: 66.6% **Lowest** Nevada: 83.1% **Third highest**	Arizona: 42.5% **Lowest** California: 81.4% **Second lowest** Nevada: 69.8% **Second Lowest**	Arizona: 57.1% **Fourth highest** California 86.9% **Third highest** Nevada: 83.1% **Third highest**	Arizona: 58.2% **Third highest** California: 82.8% **Third lowest** Nevada: 86.6% **Highest**	Arizona: 51.8% **Second lowest** California: 86.0% **Fourth highest** Nevada: 73.3% **Third lowest**

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Deliveries to Mexico	Annual delivery reduction under critically dry hydrology (median values). Values are reported as percent of allotment.	6.7%[4] **Lowest**	16.4%[4] **Second lowest**	33.3% **Second highest**	34.3% **Highest**	22.3% **Fourth highest**	22.0% **Third lowest**	23.6% **Third highest**
	Annual depletions under critically dry hydrology (median values). Values are reported as percent of allotment.	76.8% **Third Lowest**	83.6% **Highest**	67.4% **Second Lowest**	65.4% **Lowest**	78.3% **Fourth highest**	79.2% **Third highest**	81.5% **Second highest**
Lower Division States Combined Shortages	Shortage Allocation Model and Alternative Distribution Model estimated shortage impacts by water user type (Tribal, Domestic, and Non-Tribal Irrigation) under shortage conditions over a specified range of shortage volumes	Tribal:[4] 241 kaf Domestic: 277 kaf Non-Tribal Irrigation: 6 kaf	Tribal:[4] 241-489 kaf Domestic: 277-752 kaf Non-Tribal Irrigation: 6-34 kaf	Tribal: 76-378 kaf Domestic: 109-546 kaf Non-Tribal Irrigation: 316-1,578 kaf	Tribal: 209-582 kaf Domestic: 313-1,501 kaf Non-Tribal Irrigation: 2-1,211 kaf	Tribal: 209-510 kaf Domestic: 313-1,179 kaf Non-Tribal Irrigation: 2-88 kaf	Tribal: 139-357 kaf Domestic: 155-449 kaf Non-Tribal Irrigation: 206-944 kaf	<u>LB Priority 2027-2028</u> Tribal: 209-346 kaf Domestic: 313-858 kaf Non-Tribal Irrigation: 2-70 kaf <u>Priority (2029-later)</u> Tribal: 241-576 kaf Domestic: 277-1,472 kaf Non-Tribal Irrigation: 6-829 kaf

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Geomorphology and Sediment (See Section 3.5)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Water Availability	Percent of modeled futures in which *Lake Powell exceeds 3,500 feet in November or April (or both) in 100% of years*.	**19%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*	**88%** of modeled futures meet *the preferred minimum performance.*	**97%** of modeled futures meet *the preferred minimum performance.*	**46%** of modeled futures meet *the preferred minimum performance.*		**60%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Lake Powell exceeds 3,523 feet (the historical low elevation) in November or April (or both) in 100% of years*.	**3%** of modeled futures meet *the preferred minimum performance.*	**6%** of modeled futures meet *the preferred minimum performance.*	**29%** of modeled futures meet *the preferred minimum performance.*	**24%** of modeled futures meet *the preferred minimum performance.*	**12%** of modeled futures meet *the preferred minimum performance.*		**14%** of modeled futures meet *the preferred minimum performance.*
Sand Mass	Percent of modeled futures in which the *monthly Glen Canyon Dam releases are less than 900 kaf (approximately 15,000 cubic feet per second [cfs]) in at least 90% of months*. In other words, Glen Canyon Dam release rates are non-erosive in at least 90% of the simulation period.	**21%** of modeled futures meet *the preferred minimum performance.*	**50%** of modeled futures meet *the preferred minimum performance.*	**68%** of modeled futures meet *the preferred minimum performance.*	**39%** of modeled futures meet *the preferred minimum performance.*	**24%** of modeled futures meet *the preferred minimum performance.*		**41%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which the *sand mass in Marble Canyon exceeds 294,000 metric tons, the average transport capacity for a 60-hour duration high-flow experiment (HFE), in November or April at least once every four years*.	**78%** of modeled futures meet *the preferred minimum performance.*	**79%** of modeled futures meet *the preferred minimum performance.*	**79%** of modeled futures meet *the preferred minimum performance.*	**79%** of modeled futures meet *the preferred minimum performance.*	**77%** of modeled futures meet *the preferred minimum performance.*		**77%** of modeled futures meet *the preferred minimum performance.*
HFE Frequency and Duration	Percent of modeled futures in which *a spring or fall HFE of at least 60 hours occurs at least once every four years*.	**34%** of modeled futures meet *the preferred minimum performance.*	**54%** of modeled futures meet *the preferred minimum performance.*	**60%** of modeled futures meet *the preferred minimum performance.*	**64%** of modeled futures meet *the preferred minimum performance.*	**55%** of modeled futures meet *the preferred minimum performance.*		**55%** of modeled futures meet *the preferred minimum performance.*
Sandbar Volume	Percent of modeled futures in which *the maximum sediment year sandbar volume is greater than the sandbar volume at the start of the simulation period in at least 60% of years*. In other words, net sandbar growth is positive for at least 60% of the years.	**71%** of modeled futures meet *the preferred minimum performance.*	**85%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**88%** of modeled futures meet *the preferred minimum performance.*		**85%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Sand Transport	Percent of modeled futures in which *the fraction of sand mass transported by sandbar-forming flow rates (above 37,000 cfs) is at least 0.4 (40% of the sand transport).*	**49%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.	**74%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.	**82%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.	**82%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.	**77%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.		**76%** of modeled futures meet *the preferred minimum performance.* Please note that this percentage is for the full modeling period. The sand load index data used for this performance indicator does not allow for subperiod modeling.

Water Quality (See Section 3.6)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect projected **salinity**?	Percent of modeled futures in which *the salinity concentration below **Hoover Dam** is less than 723 milligrams per liter (mg/L) in 100% of years.*	**90%** of modeled futures meet *the preferred minimum performance.*	**95%** of modeled futures meet *the preferred minimum performance.*	**91%** of modeled futures meet *the preferred minimum performance.*	**94%** of modeled futures meet *the preferred minimum performance.*	**95%** of modeled futures meet *the preferred minimum performance.*	**96%** of modeled futures meet *the preferred minimum performance.*	**92%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *the salinity concentration below **Parker Dam** is less than 747 mg/L in 100% of years.*	**90%** of modeled futures meet *the preferred minimum performance.*	**94%** of modeled futures meet *the preferred minimum performance.*	**84%** of modeled futures meet *the preferred minimum performance.*	**95%** of modeled futures meet *the preferred minimum performance.*	**96%** of modeled futures meet *the preferred minimum performance.*	**96%** of modeled futures meet *the preferred minimum performance.*	**94%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *the salinity concentration **at Imperial** is less than 879 mg/L in 100% of years.*	**97%** of modeled futures meet *the preferred minimum performance.*	**97%** of modeled futures meet *the preferred minimum performance.*	**97%** of modeled futures meet *the preferred minimum performance.*	**98%** of modeled futures meet *the preferred minimum performance.*	**99%** of modeled futures meet *the preferred minimum performance.*	**99%** of modeled futures meet *the preferred minimum performance.*	**98%** of modeled futures meet *the preferred minimum performance.*
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect projected **temperature**?	Annual average daily temperature of the Colorado River **at Lees Ferry** under critically dry flow category (median values)	13.8 degrees Celsius (°C; 56.8 degrees Fahrenheit [°F])	13.8 °C (56.8 °F)	12.9 °C (55.2 °F)	13.4 °C (56.1 °F)	13.7 °C (56.7 °F)	13.7 °C (56.7 °F)	14.1 °C (57.4 °F)
	Annual maximum daily temperature of the Colorado River **at Lees Ferry** under critically dry flow category (median values)	19.9 °C (67.8 °F)	19.7 °C (67.5 °F)	17.1 °C (62.8 °F)	18.1 °C (64.6 °F)	19 °C (66.2 °F)	19 °C (66.2 °F)	20.1 °C (68.2 °F)

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect projected **temperature**? *(continued)*	Annual average daily temperature of the Colorado River **at Pearce Ferry** under critically dry flow category (median values)	16.7 °C (62.1 °F)	16.7 °C (62.1 °F)	16.6 °C (61.9 °F)	16.8 °C (62.2 °F)	16.8 °C (62.2 °F)	16.8 °C (62.2 °F)	17 °C (62.6 °F)
	Annual maximum daily temperature of the Colorado River **at Pearce Ferry** under critically dry flow category (median values)	23.3 °C (73.9 °F)	23.5 °C (74.3 °F)	23.3 °C (73.9 °F)	23.6 °C (74.5 °F)	23.6 °C (74.5 °F)	23.6 °C (74.5 °F)	23.8 °C (74.8 °F)
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect projected **dissolved oxygen**?	Percent of modeled futures in which *Lake Powell reservoir elevations stay above 3,490 feet and minimum dissolved oxygen concentration is greater than 2mg/L from Glen Canyon Dam releases in at least 90% of years.*	**20%** of modeled futures meet *the preferred minimum performance.*	**25%** of modeled futures meet *the preferred minimum performance.*	**79%** of modeled futures meet *the preferred minimum performance.*	**76%** of modeled futures meet *the preferred minimum performance.*	**34%** of modeled futures meet *the preferred minimum performance.*	**34%** of modeled futures meet *the preferred minimum performance.*	**44%** of modeled futures meet *the preferred minimum performance.*
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect **harmful algal blooms and nutrients**?	Qualitative comparison of water year minimum Lake Powell reservoir elevations under critically dry flow category (median values)	Water year minimum Lake Powell elevation median is the lowest, which would pose the **highest increased risk** for cyanobacterial blooms.	Water year minimum Lake Powell elevation median is the second lowest, which would pose **increased risk** for cyanobacterial blooms.	Water year minimum Lake Powell elevation median is highest, which would pose a **decreased risk** for cyanobacterial blooms.	Water year minimum Lake Powell elevation median is the second highest, which would pose a **decreased risk** for cyanobacterial blooms.	Water year minimum Lake Powell elevation median is third lowest compared with the other alternatives, which would pose an **increased risk** for cyanobacterial blooms compared with the Enhanced Coordination and Maximum Operational Flexibility alternatives, but a **decreased risk** compared with the No Action and Basic Coordination alternatives.		Water year minimum Lake Powell elevation median is third highest, which would pose a **decreased risk** for cyanobacterial blooms.
How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect **dilution capacity**?	Qualitative comparison of water year minimum Lake Powell reservoir elevations under critically dry flow category (median values)	Water year minimum Lake Powell elevation median is the lowest, which would pose the **greatest increased risk** of greater concentrations of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.	Water year minimum Lake Powell elevation median is the lowest, which would pose an **increased risk** of greater concentrations of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.	Water yea minimum Lake Powell elevation median is the highest, which would pose a **decreased risk** of greater concentrations of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.	Water year minimum Lake Powell elevation median is the highest, which would pose a **decreased risk** of greater concentrations of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.	Water year minimum Lake Powell elevation median is third lowest compared with the other alternatives, which would pose an **increased risk** of greater concentrations of pollutants of concern compared with the Enhanced Coordination and Maximum Operational Flexibility alternatives, but a decreased risk compared with the No Action and Basic Coordination alternatives. However, it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.		Water year minimum Lake Powell elevation median is third highest, which would pose a **decreased risk** of greater concentrations of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Air Quality (See Section 3.7)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred
Shoreline Area	Percent of modeled futures in which ***Lake Mead*** *shoreline exposure area stays below 500 square kilometers in every month*.	**54%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**75%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**88%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**93%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**81%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.		**92%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
	Percent of modeled futures in which ***Lake Powell*** *shoreline exposure area stays below 500 square kilometers in every month*.	**25%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**45%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**87%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**98%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**46%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.		**66%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
Shoreline Dust Emissions	Percent of modeled futures in which ***Lake Mead*** *shoreline dust emissions stay below 500 kilograms in every month*.	**34%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**64%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**79%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**84%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**72%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.		**74%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
	Percent of modeled futures in which ***Lake Powell*** *shoreline dust emissions stay below 450 kilograms in every month*.	**14%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**37%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**84%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**96%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.	**43%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.		**59%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
How would lake reservoir elevations and releases impact power generation and carbon dioxide equivalent (**CO_2e**) emissions?	Change in CO_2e emissions due to a loss of hydropower generation at **Glen Canyon Dam** under average hydrology conditions.	Hydropower generation would be highly affected resulting in the **tied most CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be slightly less affected than under the Representative Preferred Alternative, resulting in the **third most CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be least affected, resulting in the **tied lowest CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be similar to that under the Enhanced Coordination Alternative, resulting in the **tied lowest CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be the same as under the No Action Alternative, resulting in the **tied most CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.		Hydropower generation would be slightly less affected than under the No Action Alternative, resulting in the **second most CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred
How would lake reservoir elevations and releases impact power generation and carbon dioxide equivalent (**CO_2e**) emissions? *(continued)*	Change in CO_2e emissions due to a loss of hydropower generation at **Hoover Dam** under average hydrology conditions.	Hydropower generation would be most affected resulting in the **most CO_2e emissions**, with potential decrease in CO_2e emissions. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be less affected than under the No Action Alternative, resulting in the **second most CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be similar to that under the Maximum Operational Flexibility Alternative.	Hydropower generation would be slightly more affected than under the Supply Driven Alternative, resulting in the **second lowest CO_2e emissions** under this alternative. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be least affected, resulting in the **lowest CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases. Hydropower generation would be the same between the two Supply Driven Alternatives with the Supply Driven (LB Pro Rata) having the **lowest CO_2e emissions**.		Hydropower generation would be similar to that under the Maximum Operational Flexibility Alternative.
	Change in CO_2e emissions due to a loss of hydropower generation at **Davis Dam** under average hydrology conditions.	Hydropower generation would be the least affected, resulting in the **lowest CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be slightly less affected than under the No Action Alternative, resulting in the **second lowest CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be highly affected, resulting in the **tied most CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be similar to that under the Enhanced Coordination Alternative, resulting in the **tied most CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be similar to that under the Enhanced Coordination Alternative. Hydropower generation would be similar between the two Supply Driven Alternatives with the Supply Driven (LB Pro Rata) having the **highest CO_2e emissions**.		Hydropower generation would be slightly less affected than under the Basic Coordination Alternative, resulting in the **third lowest CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.
	Change in CO_2e emissions due to a loss of hydropower generation at **Parker Dam** under average hydrology conditions.	Hydropower generation would be the least affected, resulting in the **tied least CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be similar to that under the No Action Alternative, resulting in the **tied least CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be highly affected, resulting in the **most CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Hydropower generation would be slightly more affected than under the Representative Preferred Alternative, resulting in the **third least CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.	Under the Supply Driven Alternative (LB Priority approach), hydropower generation would be similar to that under the Maximum Flexibility Alternative. Under the Supply Driven Alternative (LB Pro Rata approach), hydropower generation would be highly affected, resulting in the **second most CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.		Hydropower generation would be slightly more affected than under the No Action Alternative, resulting in the **second least CO_2e emissions**. This is due to the inverse correlation between CO_2e emissions from alternative energy sources and generation from reservoir elevations and releases.

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Aquatic Resources (See Section 3.8)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Lake Powell elevations	Percent of modeled futures in which *Lake Powell elevation is below 3,598 feet at least 70% of months*, meaning critical habitat of Colorado Pikeminnow and Razorback Sucker is riverine (lotic) in the Colorado River Inflow.	**52%** of modeled futures meet *the preferred minimum performance.*	**49%** of modeled futures meet *the preferred minimum performance.*	**28%** of modeled futures meet *the preferred minimum performance.*	**27%** of modeled futures meet *the preferred minimum performance.*	**53%** of modeled futures meet *the preferred minimum performance.*	**53%** of modeled futures meet *the preferred minimum performance.*	**40%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Lake Powell elevation is below 3,600 feet at least 70% of months*, meaning critical habitat of Colorado Pikeminnow and Razorback Sucker is riverine (lotic) in the San Juan River Inflow.	**52%** of modeled futures meet *the preferred minimum performance.*	**50%** of modeled futures meet *the preferred minimum performance.*	**29%** of modeled futures meet *the preferred minimum performance.*	**29%** of modeled futures meet *the preferred minimum performance.*	**54%** of modeled futures meet *the preferred minimum performance.*	**54%** of modeled futures meet *the preferred minimum performance.*	**42%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Lake Powell elevation is below 3,666.5 feet in 100% of months, meaning the Paiute Farms Waterfall remains a barrier to upstream fish passage.*	**56%** of modeled futures meet *the preferred minimum performance.*	**56%** of modeled futures meet *the preferred minimum performance.*	**44%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**62%** of modeled futures meet *the preferred minimum performance.*	**62%** of modeled futures meet *the preferred minimum performance.*	**50%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *October 1 Lake Powell elevation is above 3,570 feet at least 70% of years,* meaning the risk of smallmouth bass entrainment is reduced.	**33%** of modeled futures meet *the preferred minimum performance.*	**39%** of modeled futures meet *the preferred minimum performance.*	**62%** of modeled futures meet *the preferred minimum performance.*	**60%** of modeled futures meet *the preferred minimum performance.*	**35%** of modeled futures meet *the preferred minimum performance.*	**35%** of modeled futures meet *the preferred minimum performance.*	**42%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Water Temperature	Percent of modeled futures in which *water temperature at Lees Ferry (river mile [RM] 0) never exceeds 20°C.*	**19%** of modeled futures meet *the preferred minimum performance.*	**32%** of modeled futures meet *the preferred minimum performance.*	**62%** of modeled futures meet *the preferred minimum performance.*	**60%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at the Little Colorado River Confluence (RM 62) exceeds 12°C ≥110 days in 90% of years.*	**52%** of modeled futures meet *the preferred minimum performance.*	**50%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*	**31%** of modeled futures meet *the preferred minimum performance.*	**58%** of modeled futures meet *the preferred minimum performance.*	**58%** of modeled futures meet *the preferred minimum performance.*	**44%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at the Little Colorado River Confluence (RM 62) exceeds 16°C ≥110 days in 90% of years.*	**1%** of modeled futures meet *the preferred minimum performance.*	**2%** of modeled futures meet *the preferred minimum performance.*	**4%** of modeled futures meet *the preferred minimum performance.*	**4%** of modeled futures meet *the preferred minimum performance.*	**5%** of modeled futures meet *the preferred minimum performance.*	**5%** of modeled futures meet *the preferred minimum performance.*	**6%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at the Havasu Creek Confluence (RM 157.2) exceeds 12°C ≥110 days in 90% of years.*	**91%** of modeled futures meet *the preferred minimum performance.*	**92%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**89%** of modeled futures meet *the preferred minimum performance.*	**93%** of modeled futures meet *the preferred minimum performance.*	**93%** of modeled futures meet *the preferred minimum performance.*	**93%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at the Havasu Creek Confluence (RM 157.2) exceeds 16°C ≥110 days in 90% of years.*	**43%** of modeled futures meet *the preferred minimum performance.*	**35%** of modeled futures meet *the preferred minimum performance.*	**16%** of modeled futures meet *the preferred minimum performance.*	**16%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**25%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at Pearce Ferry (RM 281) exceeds 12°C ≥110 days in 90% of years.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at Pearce Ferry (RM 281) exceeds 16°C ≥110 days in 90% of years.*	**73%** of modeled futures meet *the preferred minimum performance.*	**72%** of modeled futures meet *the preferred minimum performance.*	**51%** of modeled futures meet *the preferred minimum performance.*	**56%** of modeled futures meet *the preferred minimum performance.*	**66%** of modeled futures meet *the preferred minimum performance.*	**66%** of modeled futures meet *the preferred minimum performance.*	**58%** of modeled futures meet *the preferred minimum performance.*
Smallmouth population growth	Percent of modeled futures in which *the 5-year Smallmouth Bass growth rate (lambda) at Lees Ferry is always less than 1.*	**6%** of modeled futures meet *the preferred minimum performance.*	**21%** of modeled futures meet *the preferred minimum performance.*	**47%** of modeled futures meet *the preferred minimum performance.*	**44%** of modeled futures meet *the preferred minimum performance.*	**25%** of modeled futures meet *the preferred minimum performance.*	**25%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Smallmouth bass entrainment	Percent of modeled futures in which *the annual count of adult smallmouth bass that are entrained and survive is always less than 50 individuals.*	**0%** of modeled futures meet *the preferred minimum performance.*	**2%** of modeled futures meet *the preferred minimum performance.*	**26%** of modeled futures meet *the preferred minimum performance.*	**24%** of modeled futures meet *the preferred minimum performance.*	**4%** of modeled futures meet *the preferred minimum performance.*	**4%** of modeled futures meet *the preferred minimum performance.*	**6%** of modeled futures meet *the preferred minimum performance.*
Lake Mead elevation	Percent of modeled futures in which *Lake Mead elevation is above the historical minimum elevation of 1,040.92 feet ≥90% of months.*	**4%** of modeled futures meet *the preferred minimum performance.*	**11%** of modeled futures meet *the preferred minimum performance.*	**14%** of modeled futures meet *the preferred minimum performance.*	**17%** of modeled futures meet *the preferred minimum performance.*	**21%** of modeled futures meet *the preferred minimum performance.*	**27%** of modeled futures meet *the preferred minimum performance.*	**17%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Colorado River water levels at Pearce Ferry Rapid are below 1,090 Feet ≥90% of months.*	**78%** of modeled futures meet *the preferred minimum performance.*	**59%** of modeled futures meet *the preferred minimum performance.*	**31%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**20%** of modeled futures meet *the preferred minimum performance.*	**39%** of modeled futures meet *the preferred minimum performance.*
Hoover Dam releases	Percent of modeled futures in which *monthly releases from Hoover Dam are within the range observed during 2008–2025, in 100% of months.*	**88%** of modeled futures meet *the preferred minimum performance.*	**82%** of modeled futures meet *the preferred minimum performance.*	**47%** of modeled futures meet *the preferred minimum performance.*	**32%** of modeled futures meet *the preferred minimum performance.*	**64%** of modeled futures meet *the preferred minimum performance.*	**61%** of modeled futures meet *the preferred minimum performance.*	**41%** of modeled futures meet *the preferred minimum performance.*

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Vegetation Including Special Status Species (See Section 3.9)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Vegetation, including special status plant species	Marsh habitat (Lake Powell, Lake Mead, and Hoover Dam to SIB Reaches) – Changes in water fluctuations within a single year compared to historical conditions.	The No Action Alternative is **among the middle performing** alternative for the Lake Powell reach because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The No Action Alternative is **among the best performing** alternatives for the Hoover Dam to SIB reaches because it has annual variability similar to historic conditions. The No Action Alternative is **among the least performing** alternatives for the Lake Mead reach because its annual variability is least like historic conditions.	The Basic Coordination Alternative is **among the middle performing** alternatives for the Lake Powell reach because is neither the most similar nor the least similar to historic conditions for these reaches. The Basic Coordination Alternative is **among the best performing** alternatives for the Lake Mead and Hoover Dam to SIB reaches because it has annual variability similar to historic conditions.	The Enhanced Coordination Alternative is **among the best performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Enhanced Coordination Alternative is **among the least performing** alternatives for the Lake Mead and Hoover Dam to SIB reach because its annual variability is least like historic conditions.	The Maximum Operational Flexibility Alternative is **among the best performing** alternatives for the Lake Powell, Lake Mead, and Hoover Dam to the SIB reaches because it has annual variability similar to historic conditions.	The Supply Driven Alternative is **among the best performing** alternative for the Hoover Dam to SIB reach because it has annual variability similar to historic conditions. The Supply Driven Alternative is **among the middle performing** alternative for the Lake Mead reach because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The Supply Driven Alternative is **among the least performing** alternatives for Lake Powell because its annual variability is least like historic conditions.		The Representative Preferred Alternative is **among the middle performing** alternatives for the Lake Powell and Lake Mead reaches because is neither the most similar nor the least similar to historic conditions for these reaches in the first decade. The Representative Preferred Alternative is **among the least performing** alternatives for the Hoover Dam to the SIB because its annual variability is least like historic conditions in the first decade. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.
	Woody riparian habitat (Lake Powell, Lake Mead, and Hoover Dam to SIB Reaches) – Changes in water fluctuations in the preceding 5 years compared to historical conditions.	The No Action Alternative is **among the middle performing** alternative for the Lake Powell, Lake Mead, and Hoover Dam to SIB reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches.	The Basic Coordination Alternative is **among the middle performing** alternative for the Lake Powell because the annual variability is neither the most similar nor the least similar to historic conditions for this reach. The Basic Coordination Alternative is **among the best performing** alternatives for the Lake Mead and Hoover Dam to SIB reaches because it has annual variability similar to historic conditions.	The Enhanced Coordination Alternative is **among the best performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Enhanced Coordination Alternative is **among the least performing** alternatives for Lake Mead and the Hoover Dam to SIB reach because its annual variability is least like historic conditions.	The Maximum Operational Flexibility Alternative is **among the middle performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Maximum Operational Flexibility Alternative is **among the best performing** alternatives for the Lake Mead reach because it has annual variability similar to historic conditions. The Maximum Operational Flexibility Alternative is **among the least performing** alternatives for the Hoover Dam to SIB reach because its annual variability is least like historic conditions.	The Supply Driven Alternative is **never the best performing** alternative because it never has variability most similar to historic conditions. The Supply Driven Alternative is **among the middle performing** alternative for the Lake Mead and Hoover Dam to SIB reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The Supply Driven Alternative is **among the least performing** alternatives for the Lake Powell reach because its annual variability is least like historic conditions.		The Representative Preferred Alternative is **among the middle performing** alternatives for all reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	**Basic Coordination Alternative**	**Enhanced Coordination Alternative**	**Maximum Operational Flexibility Alternative**	**Supply Driven Alternative (LB Priority)**	**Supply Driven Alternative (LB Pro Rata)**	**Representative Preferred Alternative**
Vegetation, including special status plant species *(continued)*	Upland habitat (Lake Powell, Lake Mead, and Hoover Dam to SIB Reaches) – Changes in water fluctuations in either the preceding single year or preceding 5 years compared to historical conditions.	Upland habitat would be gained or lost depending on whether conditions are suitable for marsh or woody riparian habitat (see above).						
	Marsh habitat suitable area (Glen Canyon Dam to Lake Mead Reach) - A change from the median and interquartile ranges from modeled historic conditions	Considering all modeled natural flow conditions, no alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach. Across all sub-reaches, there is a general trend of less suitable habitat area for marsh vegetation under wetter conditions and more suitable habitat area under drier conditions compared to modeled historic conditions.						
	Woody Riparian habitat suitable area (Glen Canyon Dam to Lake Mead Reach) - A change from the median and interquartile ranges from modeled historic conditions.	Considering all modeled natural flow conditions, no alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach. Across all sub-reaches, there is a general trend of less suitable habitat area for woody riparian vegetation under wetter conditions and more suitable habitat area under drier conditions compared to modeled historic conditions.						
	Upland habitat suitable area	Upland habitat would be gained or lost depending on whether conditions are suitable for marsh or woody riparian habitat (see above).						
	Native Species Richness (Glen Canyon Dam to Lake Mead Reach) - A change from the median and interquartile ranges from modeled historic conditions.	Considering all modeled natural flow conditions and sub-reaches, no alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach. All alternatives show decreased native species richness compared to modeled historic conditions under all flow conditions.						
	Proportion Native Species Cover (Glen Canyon Dam to Lake Mead Reach) - A change from the median and interquartile ranges from modeled historic conditions.	Considering all modeled natural flow conditions, no alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach. Across all sub-reaches, there is a general trend of less proportion of native species cover under wetter conditions and more proportion of native species cover under drier conditions compared to modeled historic conditions.						

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Vegetation, including special status plant species *(continued)*	Annual Total Vegetation Cover (Glen Canyon Dam to Lake Mead Reach) - A change from the median and interquartile ranges from modeled historic conditions.	Considering all modeled natural flow conditions, no alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach. Across all sub-reaches, there is a general trend of less annual total vegetation cover under wetter conditions and more annual total vegetation cover under drier conditions compared to modeled historic conditions.						

Terrestrial Wildlife Including Special Status Species (See Section 3.10)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Terrestrial wildlife species habitat availability, including for special status species	Terrestrial wildlife species using marsh habitat – Changes in water fluctuations within a single year compared to historical conditions.	The No Action Alternative is **among the middle performing** alternative for the Lake Powell reach because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The No Action Alternative is **among the best performing** alternatives for the Hoover Dam to SIB reaches because it has annual variability similar to historic conditions. The No Action Alternative is **among the least performing** alternatives for the Lake Mead reach because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Basic Coordination Alternative is **among the middle performing** alternatives for the Lake Powell reach because is neither the most similar nor the least similar to historic conditions for these reaches. The Basic Coordination Alternative is **among the best performing** alternatives for the Lake Mead and Hoover Dam to SIB reaches because it has annual variability similar to historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Enhanced Coordination Alternative is **among the best performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Enhanced Coordination Alternative is **among the least performing** alternatives for the Lake Mead and Hoover Dam to SIB reach because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Maximum Operational Flexibility Alternative is **among the best performing** alternatives for the Lake Powell, Lake Mead, and Hoover Dam to the SIB reaches because it has annual variability similar to historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Supply Driven Alternative is **among the best performing** alternative for the Hoover Dam to SIB reach because it has annual variability similar to historic conditions. The Supply Driven Alternative is **among the middle performing** alternative for the Lake Mead reach because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The Supply Driven Alternative is **among the least performing** alternatives for Lake Powell because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.		The Representative Preferred Alternative is **among the middle performing** alternatives for the Lake Powell and Lake Mead reaches because is neither the most similar nor the least similar to historic conditions for these reaches in the first decade. The Representative Preferred Alternative is **among the least performing** alternatives for the Hoover Dam to the SIB because its annual variability is least like historic conditions in the first decade. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.

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Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Terrestrial wildlife species habitat availability, including for special status species *(continued)*	Terrestrial wildlife species using woody riparian habitat – Changes in water fluctuations in the preceding 5 years compared to historical conditions.	The No Action Alternative is **among the middle performing** alternative for the Lake Powell, Lake Mead, and Hoover Dam to SIB reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Basic Coordination Alternative is **among the middle performing** alternative for the Lake Powell because the annual variability is neither the most similar nor the least similar to historic conditions for this reach. The Basic Coordination Alternative is **among the best performing** alternatives for the Lake Mead and Hoover Dam to SIB reaches because it has annual variability similar to historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Enhanced Coordination Alternative is **among the best performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Enhanced Coordination Alternative is **among the least performing** alternatives for Lake Mead and the Hoover Dam to SIB reach because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Maximum Operational Flexibility Alternative is **among the middle performing** alternatives for the Lake Powell reach because it has annual variability similar to historic conditions. The Maximum Operational Flexibility Alternative is **among the best performing** alternatives for the Lake Mead reach because it has annual variability similar to historic conditions. The Maximum Operational Flexibility Alternative is **among the least performing** alternatives for the Hoover Dam to SIB reach because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.	The Supply Driven Alternative is **never the best performing** alternative because it never has variability most similar to historic conditions. The Supply Driven Alternative is **among the middle performing** alternative for the Lake Mead and Hoover Dam to SIB reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. The Supply Driven Alternative is **among the least performing** alternatives for the Lake Powell reach because its annual variability is least like historic conditions. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.		The Representative Preferred Alternative is **among the middle performing** alternatives for all reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.
	Terrestrial wildlife species using upland habitat – Changes in water fluctuations in either the preceding single year or preceding 5 years compared to historical conditions.	Upland habitat would be gained or lost depending on whether conditions are suitable for marsh or woody riparian habitat (see above).						

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Cultural Resources (See Section 3.11)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Projected end-of-year lake elevations that may expose cultural resources to damage from wave action, wet/dry cycling, or increased ease of access	Projected end-of-year lake elevations for Lake Powell (EOWY) and Lake Mead (EOCY) and number of cultural resources potentially impacted	Lake Powell: Under average conditions, median water levels fall below 3,550 feet exposing at least 316 archaeological sites. Under critically dry conditions, median water levels drop below 3,440 feet, potentially leaving the most sites exposed with at least 415 sites exposed. Lake Mead: During average hydrologic conditions, median elevations are around 990below 980 feet potentially exposing at least 301 known sites. In critically dry conditions, all 310 sites would likely be exposed due to low reservoir elevations.	Lake Powell: Under average conditions, median water levels fall below 3,570 feet exposing at least 316 archaeological sites. Under critically dry conditions, median water levels drop below 3,490 feet with at least 415 sites exposed. Lake Mead: During average hydrological conditions, median elevations are around or below 1,060 feet exposing at least 280 sites. In critically dry conditions, median elevations drop below 980 feet, exposing at least 296 sites would likely be exposed.	Lake Powell: Under average conditions, median water levels drop to around 3,610 feet, leaving at more than 138 sites exposed. Under critically dry conditions, median water levels drop below 3,560 feet, potentially leaving at least 316 sites exposed. Lake Mead: Under average conditions, median elevations are around 1,110 feet exposing up to at least 265 sites. In critically dry conditions, all 310 sites could be exposed due to low reservoir elevations.	Lake Powell: Under average conditions, median water levels drop to around 3,600 feet, leaving at least 197 sites exposed. Under critically dry conditions, median water levels drop below 3,550 feet, potentially leaving at least 316 site exposed. Lake Mead: Under average conditions, median elevations are around or below 1,130 feet exposing up to at least 245 sites. Under critically dry conditions, median elevations are around 1,000 feet leaving at least 296 sites exposed.	Lake Powell: Under average conditions, median elevations are around 3,580 feet leaving at least 280 sites exposed. Under critically dry conditions, median water levels drop below 3,490 feet, potentially leaving the most sites exposed with at least 415 sites exposed. Lake Mead: During average conditions, median elevations are around or below 1,150 feet exposing at least 227 known sites. Under critically dry conditions, minimum elevations are below 1,030 feet and could potentially expose at least 291 sites. .		Lake Powell: Under average conditions, median elevations are just below 3,600 feet leaving at least 249 sites exposed. Under critically dry conditions, median water levels drop below 3,510 feet, potentially leaving the most sites exposed with at least 316 sites exposed. Lake Mead: During average conditions, median elevations are around or below 1,100 feet exposing at least 265 known sites. Under critically dry conditions, minimum elevations are below 990 feet and could potentially expose at least 296 sites.
	Lake Powell: Percent of modeled futures for the first decadal period (2027–2039) in which *the preservation risk at Lake Powell is below 2.72 in at least 90% of months* Lake Mead: Percent of modeled futures for the first decadal period (2027–2039) in which *the preservation risk at Lake Mead is below 2.24 in at least 90% of months*	Lake Powell: **12%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **1%** of modeled futures meet *the preferred minimum performance*.	Lake Powell: **14%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **2%** of modeled futures meet *the preferred minimum performance*.	Lake Powell: **30%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **2%** of modeled futures meet *the preferred minimum performance*.	Lake Powell: **25%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **3%** of modeled futures meet *the preferred minimum performance*.	Lake Powell: **12%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **5%** of modeled futures meet *the preferred minimum performance*.		Lake Powell: **16%** of modeled futures meet *the preferred minimum performance*. Lake Mead: **3%** of modeled futures meet *the preferred minimum performance*.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Projected changes in river flows that may contribute to erosion and exposure of cultural resources that may expose sites to damage from erosion, wet/dry cycling, or increased ease of access	Projected releases from dams and forecasted river flow volumes that are outside past releases or flows	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.		Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.
Projected availability of sediments along the river which may be transported by wind and deposited on archaeological sites	Percent of modeled futures for the first decadal period (2027-2039) in which *annual sand area >50th and vegetation cover <50th percentile or sandbar volume >1.5 initial condition at least one out of every 3 years*	**38%** of modeled futures meet *the preferred minimum performance*.	**19%** of modeled futures meet *the preferred minimum performance*.	**35%** of modeled futures meet *the preferred minimum performance*.	**30%** of modeled futures meet *the preferred minimum performance*.	**9%** of modeled futures meet *the preferred minimum performance*.	**9%** of modeled futures meet *the preferred minimum performance*.	**17%** of modeled futures meet *the preferred minimum performance*.

Paleontological Resources (See Section 3.12)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Paleontological preservation risk due to dam operations	Percent of modeled futures for the first decadal period (2027–2039) in which *monthly preservation risk rank at **Lake Powell** stays below 2.9 at least 90% of months*	**10%** of modeled futures meet *the preferred minimum performance.*	**11%** of modeled futures meet *the preferred minimum performance.*	**24%** of modeled futures meet *the preferred minimum performance.*	**21%** of modeled futures meet *the preferred minimum performance.*	**10%** of modeled futures meet *the preferred minimum performance.*		**13%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027–2039) in which *monthly preservation risk rank at **Lake Mead** stays below 2.3 at least 90% of months*	**1%** of modeled futures meet *the preferred minimum performance.*	**1%** of modeled futures meet *the preferred minimum performance.*	**2%** of modeled futures meet *the preferred minimum performance.*	**2%** of modeled futures meet *the preferred minimum performance.*	**4%** of modeled futures meet *the preferred minimum performance.*		**3%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Paleontological resource preservation and stability due to altered sediment transport	Percent of modeled futures for the first decadal period (2027-2039) in which *annual sand area >50th and vegetation cover <50th percentile or sandbar volume >1.5 initial condition at least one out of every 3 years*	**38%** of modeled futures meet *the preferred minimum performance.*	**19%** of modeled futures meet *the preferred minimum performance.*	**35%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**9%** of modeled futures meet *the preferred minimum performance.*		**9%** of modeled futures meet *the preferred minimum performance.*
Paleontological resource preservation and stability due to altered sediment transport *(continued)*	Percent of modeled futures in which *the fraction of sand mass transported by sandbar-forming flow rates (above 37,000 cfs) is at least 0.4 over 34 years (40% of the sand transport)*	**44%** of modeled futures meet *the preferred minimum performance.*	**75%** of modeled futures meet *the preferred minimum performance.*	**83%** of modeled futures meet *the preferred minimum performance.*	**85%** of modeled futures meet *the preferred minimum performance.*	**78%** of modeled futures meet *the preferred minimum performance.*		**76%** of modeled futures meet *the preferred minimum performance.*
Impacts of increased disturbance, unauthorized collection, and recreational impacts on paleontological resources due to dam operations and altered water levels	Percent of modeled futures for the first decadal period (2027-2039) in which *Lake Powell elevation stays above 3,500 feet in 100% of months*	**4%** of modeled futures meet *the preferred minimum performance*	**19%** of modeled futures meet *the preferred minimum*	**81%** of modeled futures meet *the preferred minimum performance*	**94%** of modeled futures meet *the preferred minimum performance*	**35%** of modeled futures meet *the preferred minimum performance*		**49%** of modeled futures meet *the preferred minimum performance* during the 2027-2039 modeling period.
	Percent of modeled futures for the first decadal period (2027-2039) in which *Lake Mead elevation stays above 975 feet in 100% of months*	**32%** of modeled futures meet *the preferred minimum performance*	**62%** of modeled futures meet *the preferred minimum performance*	**74%** of modeled futures meet *the preferred minimum performance*	**77%** of modeled futures meet *the preferred minimum performance*	**69%** of modeled futures meet *the preferred minimum performance*	**81%** of modeled futures meet *the preferred minimum performance*	**66%** of modeled futures meet *the preferred minimum performance*

Tribal Resources (See Section 3.13)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir Elevations that may expose traditional cultural properties, archaeological sites, or sacred sites to increased access and visitation	Lake Powell EOWY elevations	Lowest elevations in the critcally dry flow category exposing the greatest number of sites to visitation	Second lowest elevations in the critcally dry flow category	Highest elevations in the critcally dry flow category exposing the fewest number of sites to visitation	Second highest elevations in the critcally dry flow category	Tied in the middle performing for elevations in the critcally dry flow category	Tied in the middle performing for elevations in the critcally dry flow category	Third highest median elevations in the critcally dry flow category.
	Lake Mead EOCY elevations in feet	Lowest elevations in all flow categories exposing the greatest number of sites to visitation	Second lowest elevations in all flow categories	Third lowest elevations in all flow categories	Third highest elevations in all flow categories	Second highest elevations in all flow categories	Highest elevations in all flow categories exposing the fewest number of sites to visitation	Third lowest median elevations in the critcally dry flow category.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Projected changes in river flows that may contribute to erosion and exposure of archaeological sites or sacred sites	Projected releases from dams and forecasted river flow volumes that are outside past releases or flows	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.	Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.		Under average hydrologic conditions, releases fall within past volumes for the Glen Canyon Dam to Lake Mead reach and Hoover Dam to Lake Mohave. During critically dry conditions, release volumes may drop below past releases; however, impacts would only be for sites close to riverbank. No impacts below Lake Mohave.
Projected changes in natural resources important to Native Americans including riparian vegetation and wildlife	Woody riparian habitat most similar to historic conditions	The No Action Alternative is among the middle performing alternative for the Lake Powell, Lake Mead, and Hoover Dam to SIB reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches.	The Basic Coordination Alternative is among the middle performing alternative for the Lake Powell because the annual variability is neither the most similar nor the least similar to historic conditions for this reach. The Basic Coordination Alternative is among the best performing alternatives for the Lake Mead and Hoover Dam to SIB reaches because it has annual variability similar to historic conditions.	Among the best performing alternatives for the Lake Powell reach and among the least performing alternatives for Lake Mead and the Hoover Dam to SIB reach.	Among the middle performing alternatives for the Lake Powell reach and among the best performing alternatives for the Lake Mead reach. Among the least performing alternatives for the Hoover Dam to SIB reach.	Never the best performing alternative but among the middle performing alternatives for the Lake Mead reach because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. Alternative is among the middle performing alternative for the Lake Mead and Hoover Dam to SIB reaches. Among the least performing alternatives for the Lake Powell reach.		The Representative Preferred Alternative is among the middle performing alternatives for all reaches because the annual variability is neither the most similar nor the least similar to historic conditions for these reaches. Considering all modeled natural flow conditions, no Alternative is better performing compared to the modeled historic conditions in the Glen Canyon Dam to Lake Mead reach.
	Critical fish habitat (Colorado River)	Modeling presented for aquatic species suggests that 52% of futures would meet acceptable critical habitat performance standards	Modeling suggests 49% of futures would meet acceptable critical habitat performance standards	Modeling suggests that 28% of futures would meet acceptable critical habitat performance standards	Modeling suggests that 27% of futures would meet acceptable critical habitat performance standards	Modeling suggests that 53% of futures would meet acceptable critical habitat performance standards		Modeling suggests that 40% of futures would meet acceptable critical habitat performance standards

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Recreation (See Section 3.14)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir elevation impacts on shoreline recreational facilities, reservoir boating, and sport fishing opportunities	Percent of modeled futures for the first decadal period (2027-2039) in which *the proportion of **Lake Powell** recreation sites open stays above 0.6 (historical benchmark) for all summer months (May 31 – August 31) each year*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*	**0%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which *the proportion of **Lake Mead** recreation sites open stays above 0.8 (historical benchmark) for all summer months (May 31 – August 31) each year*	**3%** of modeled futures meet *the preferred minimum performance.*	**6%** of modeled futures meet *the preferred minimum performance.*	**5%** of modeled futures meet *the preferred minimum performance.*	**8%** of modeled futures meet *the preferred minimum performance.*	**13%** of modeled futures meet *the preferred minimum performance.*	**16%** of modeled futures meet *the preferred minimum performance.*	**7%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which ***Lake Powell** elevation is above the identified boating hazard minimum (3,620 feet) for at least 20% of months*	**47%** of modeled futures meet *the preferred minimum performance.*	**50%** of modeled futures meet *the preferred minimum performance.*	**64%** of modeled futures meet *the preferred minimum performance.*	**69%** of modeled futures meet *the preferred minimum performance.*	**43%** of modeled futures meet *the preferred minimum performance.*	**43%** of modeled futures meet *the preferred minimum performance.*	**55%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which ***Lake Powell** elevation is above the critical threshold for most boat launch facilities (3,590 feet) for at least 60% of months*	**32%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**34%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**56%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**55%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**31%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**31%** of modeled futures in first 10 years meet *the preferred minimum performance.*	**38%** of modeled futures in first 10 years meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which ***Lake Mead** elevation is above the identified boating hazard minimum (1,170 feet) for at least 10% of months*	**12%** of modeled futures meet *the preferred minimum performance.*	**19%** of modeled futures meet *the preferred minimum performance.*	**32%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*	**44%** of modeled futures meet *the preferred minimum performance.*	**49%** of modeled futures meet *the preferred minimum performance.*	**31%** of modeled futures in first 10 years meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which ***Lake Mead** elevation is 1,040 feet or greater for at least 90% of months*	**5%** of modeled futures meet *the preferred minimum performance.*	**12%** of modeled futures meet *the preferred minimum performance.*	**16%** of modeled futures meet *the preferred minimum performance.*	**18%** of modeled futures meet *the preferred minimum performance.*	**22%** of modeled futures meet *the preferred minimum performance.*	**28%** of modeled futures meet *the preferred minimum performance.*	**18%** of modeled futures meet *the preferred minimum performance.*
Glen Canyon Dam releases impacts on whitewater boating and sport fishing	Percent of modeled futures for the first decadal period (2027-2039) in which *daytime flows (7am – 7pm) below Glen Canyon Dam are at least 5,000 cfs every day*	**92%** of modeled futures meet *the preferred minimum performance.*	**94%** of modeled futures meet *the preferred minimum performance.*	**99%** of modeled futures meet *the preferred minimum performance.*	**40%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**100%** of modeled futures meet *the preferred minimum performance.*	**98%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures for the first decadal period (2027-2039) in which *daytime flows (7am – 7pm) below Glen Canyon Dam are at least 8,000 cfs at least 95% of days*	**75%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**1%** of modeled futures meet *the preferred minimum performance.*	**22%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**60%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *water temperature at Lees Ferry (river mile [RM] 0) never exceeds 20°C.*	**19%** of modeled futures meet *the preferred minimum performance.*	**32%** of modeled futures meet *the preferred minimum performance.*	**62%** of modeled futures meet *the preferred minimum performance.*	**60%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**30%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Dams and Electrical Power Resources (See Section 3.15)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Reservoir Elevations and Power Pool Robustness	Percent of modeled futures in which *Lake Powell elevation is always above minimum power pool (3,490 feet).*	**25%** of modeled futures meet *the preferred minimum performance.*	**45%** of modeled futures meet *the preferred minimum performance.*	**87%** of modeled futures meet *the preferred minimum performance.*	**98%** of modeled futures meet *the preferred minimum performance.*	**46%** of modeled futures meet *the preferred minimum performance.*	**46%** of modeled futures meet *the preferred minimum performance.*	**66%** of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Lake Mead elevation is always above minimum power pool (950 feet).*	**43%** of modeled futures meet *the preferred minimum performance.*	**68%** of modeled futures meet *the preferred minimum performance.*	**86%** of modeled futures meet *the preferred minimum performance.*	**90%** of modeled futures meet *the preferred minimum performance.*	**77%** of modeled futures meet *the preferred minimum performance.*	**88%** of modeled futures meet *the preferred minimum performance.*	**84**% of modeled futures meet *the preferred minimum performance.*
	Percent of modeled futures in which *Lake Mead elevation is always above the high-head turbines (1,035 feet)*	**7%** of modeled futures meet *the preferred minimum performance.*	**18%** of modeled futures meet *the preferred minimum performance.*	**23%** of modeled futures meet *the preferred minimum performance.*	**22%** of modeled futures meet *the preferred minimum performance.*	**26%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*	**25**% of modeled futures meet *the preferred minimum performance.*
Energy Capacity of the Glen Canyon Dam and Hoover Dam Powerplants	August power capacity (megawatt [MW]) under average hydrology conditions	Glen Canyon Dam: 500-635 MW Hoover Dam: 125-1,240 MW	Glen Canyon Dam: 580-750 MW Hoover Dam: 400-1,550 MW	Glen Canyon Dam: 590-790 MW Hoover Dam: 1,300-1,600 MW	Glen Canyon Dam: 600-650 MW Hoover Dam: 1,200-1,700 MW	Glen Canyon Dam: 620 -740 MW Hoover Dam: 1,380-1,700 MW	Glen Canyon Dam: 620 - 740 MW Hoover Dam: 1,490 -1,725 MW	Glen Canyon Dam: 600 - 740 MW Hoover Dam: 1,190 -1.650 MW
	August power capacity (MW) under critically dry hydrology conditions	Glen Canyon Dam: 0-520 MW Hoover Dam: 0-250 MW	Glen Canyon Dam: 0-525 MW Hoover Dam: 0-1,260 MW	Glen Canyon Dam: 250-625 MW Hoover Dam: 200 -1,270 MW	Glen Canyon Dam: 225-380 MW Hoover Dam: 249 – 1,425 MW	Glen Canyon Dam: 0-390 MW Hoover Dam: 0-1,500 MW	Glen Canyon Dam: 0-390 MW Hoover Dam: 240-1,550 MW	Glen Canyon Dam: 225 - 510 MW Hoover Dam: 100 -450 MW
	Water year generation (Megawatt Hours [MWhs under average hydrology conditions	Glen Canyon Dam: 3-4 MWhs Hoover Dam: 1.3-3.3 MWhs	Glen Canyon Dam: 3.1-3.7 MWhs Hoover Dam: 2.8-3.6 MWhs	Glen Canyon Dam: 3-4.1 MWhs Hoover Dam: 2.7-3.8 MWhs	Glen Canyon Dam: 3.3-4 MWhs Hoover Dam: 2.9-3.8 MWhs	Glen Canyon Dam: 3.1-3.6 MWhs Hoover Dam: 2.9-3.9 MWhs	Glen Canyon Dam: 3.1-3.6 MWhs Hoover Dam: 2.9-4 MWhs	Glen Canyon Dam: 3.3-3.6 MWhs Hoover Dam: 2.7—3.8 MWhs
	Water year generation (MWhs) under critically dry hydrology conditions	Glen Canyon Dam: 0-2 MWhs Hoover Dam: 0-2.2 MWhs	Glen Canyon Dam: 0-2.3 MWhs Hoover Dam: 0-3 MWhs	Glen Canyon Dam: 1.8-2.7 MWhs Hoover Dam: 1.7-2.7 MWhs	Glen Canyon Dam: 1.9-2.4 MWhs Hoover Dam: 1.9-3 MWhs	Glen Canyon Dam: 0-2 MWhs Hoover Dam: 0.4-3.2 MWhs	Glen Canyon Dam: 0-2 MWhs Hoover Dam: 2-3.1 MWh s	Glen Canyon Dam: 0.7-2.1 MWhs Hoover Dam: 1.0-3.4 MWhs

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Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Glen Canyon Dam and Hoover Dam spillway infrastructure	Percent of modeled futures in which *the January 1 Lake Powell elevation does not exceed 3,684 feet, the target elevation to preserve flood control storage, in at least 90% of years*.	**80%** of modeled futures meet *the preferred minimum performance*.	**84%** of modeled futures meet *the preferred minimum performance*.	**75%** of modeled futures meet *the preferred minimum performance*.	**72%** of modeled futures meet *the preferred minimum performance*.	**87%** of modeled futures meet *the preferred minimum performance*.	**87%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.
	Percent of modeled futures in which *Lake Powell elevation is below 3,700 feet in 100% of months*. The higher the percentage, the more likely Lake Powell will remain below the spillway crest.	**75%** of modeled futures meet *the preferred minimum performance*.	**76%** of modeled futures meet *the preferred minimum performance*.	**69%** of modeled futures meet *the preferred minimum performance*.	**66%** of modeled futures meet *the preferred minimum performance*.	**82%** of modeled futures meet *the preferred minimum performance*.	**82%** of modeled futures meet *the preferred minimum performance*.	**78%** of modeled futures meet *the preferred minimum performance*.
	Percent of modeled futures in which *the Glen Canyon Dam spillway is not utilized*.	**87%** of modeled futures meet *the preferred minimum performance*.	**87%** of modeled futures meet *the preferred minimum performance*.	**84%** of modeled futures meet *the preferred minimum performance*.	**81%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.
	Percent of modeled futures in which *Lake Mead stays below 1,205.4 feet, the elevation of the Hoover Dam spillway crest, in at least 90% of months*	**93%** of modeled futures meet *the preferred minimum performance*.	**90%** of modeled futures meet *the preferred minimum performance*.	**80%** of modeled futures meet *the preferred minimum performance*.	**78%** of modeled futures meet *the preferred minimum performance*.	**72%** of modeled futures meet *the preferred minimum performance*.	**68%** of modeled futures meet *the preferred minimum performance*.	**81%** of modeled futures meet *the preferred minimum performance*.
	Percent of modeled futures in which *Lake Mead elevation stays below 1,219 feet in at least 90% of months*. The higher the percentage, the more likely Lake Mead will have reserve flood control storage.	**99%** of modeled futures meet *the preferred minimum performance*.	**98%** of modeled futures meet *the preferred minimum performance*.	**95%** of modeled futures meet *the preferred minimum performance*.	**93%** of modeled futures meet *the preferred minimum performance*.	**86%** of modeled futures meet *the preferred minimum performance*.	**84%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.
	Percent of modeled futures in which *Lake Mead elevation never exceeds 1,226.9 feet*. At this elevation the volume of spillway discharge triggers a "Imminent Life-Threatening Emergency" response.	**98%** of modeled futures meet *the preferred minimum performance*.	**97%** of modeled futures meet *the preferred minimum performance*.	**94%** of modeled futures meet *the preferred minimum performance*.	**94%** of modeled futures meet *the preferred minimum performance*.	**89%** of modeled futures meet *the preferred minimum performance*.	**88%** of modeled futures meet *the preferred minimum performance*.	**93%** of modeled futures meet *the preferred minimum performance*.
Glen Canyon Dam electricity rates	Glen Canyon Dam number of rate changes	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 33% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 36% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 44% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 44% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 32% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 32% of futures meet the minimum performance level.	Results indicate one or fewer major rate increases during the 2027–2039 modeling period. For maintaining zero rate increases, 37% of futures meet the minimum performance level.

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Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	**Basic Coordination Alternative**	**Enhanced Coordination Alternative**	**Maximum Operational Flexibility Alternative**	**Supply Driven Alternative (LB Priority)**	**Supply Driven Alternative (LB Pro Rata)**	**Representative Preferred Alternative**
Annual Market Value of the Glen Canyon Dam and Hoover Dam Powerplants	Annual Market Value (million dollars) of Glen Canyon Dam Generation under average hydrology conditions	Glen Canyon Dam: $160 million - $230 million Hoover Dam: $50 million - $125 million	Glen Canyon Dam: $190 million - $210 million Hoover Dam: $100 million - $190 million	Glen Canyon Dam: $190 million - $250 million Hoover Dam: $145 million - $190 million	Glen Canyon Dam: $200 million - $250 million Hoover Dam: $140 million - $200 million	Glen Canyon Dam: $190 million - $210 million Hoover Dam: $150 million - $210 million	Glen Canyon Dam: $190 million - $210 million Hoover Dam: $150 million - $215M	Glen Canyon Dam: $200 million - $210 million Hoover Dam: $140 million - $200 million
	Annual Market Value (million dollars) of Hoover Dam Generation under critically dry hydrology conditions	Glen Canyon Dam: $0 - $100 million Hoover Dam: $0 - $100 million	Glen Canyon Dam: $0 - $100 million Hoover Dam: $0 - $110 million	Glen Canyon Dam: $100 million - $160million Hoover Dam: $75 million - $125 million	Glen Canyon Dam: $100 million - $150 million Hoover Dam: $80 million - $145 million	Glen Canyon Dam: $0 million - $100 million Hoover Dam: $0 - $155 million	Glen Canyon Dam: $0 million - $100 million Hoover Dam: $90 million - $160 million	Glen Canyon Dam: $40 million - $130 million Hoover Dam: $40 million - $160 million

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Socioeconomics (See Section 3.16)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and social conditions associated with changes in agriculture due to water shortages	Level of annual impacts on acres of fallowed agricultural lands during a maximum shortage	For Arizona non-tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 0.6 maf, with an increase of about 1,000 fallowed acres.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the No Action Alternative is among the alternatives with the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 0.6 maf, with no change in fallowed acres. For Arizona tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 0.6 maf, with an increase of about 12,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **low level of impact** on acres of fallowed lands during a maximum shortage of 1.5 maf, with an increase of about 7,000 fallowed acres.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 1.5 maf, with no change in fallowed acres. For Arizona tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **medium level of impact** on acres of fallowed lands during a maximum shortage of 1.5 maf, with an increase of about 50,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **medium level of impact** on acres of fallowed lands during a maximum shortage of 3.0 maf, with an increase of about 62,000 fallowed acres. For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Enhanced Coordination Alternative has the **highest level of impact** on acres of fallowed lands during a maximum shortage of 3.0 maf, with an increase of about 283,000, 5,000, and 700 fallowed acres for California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, respectively. For Arizona tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **medium level of impact** on acres of fallowed lands during a maximum shortage of 3.0 maf, with an increase of about 39,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on acres of fallowed lands during a maximum shortage of 4.0 maf, with an increase of about 103,000 fallowed acres. For California non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 4.0 maf, with an increase of about 227,000 fallowed acres. For California tribal and Nevada tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 4.0 maf, with no change in fallowed acres. For Arizona tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on acres of fallowed lands during a maximum shortage of 4.0 maf, with an increase of about 68,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 8,000 fallowed acres. For California non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 12,000 fallowed acres. For California tribal and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with no change in fallowed acres. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 54,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **medium level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 61,000 fallowed acres. For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 153,000, 3,000, and 500 fallowed acres for California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, respectively. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **medium level of impact** on acres of fallowed lands during a maximum shortage of 2.1 maf, with an increase of about 39,000 fallowed acres.	For Arizona non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 3.6 maf, with an increase of about 91,000 fallowed acres. For California non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 3.6 maf, with an increase of about 151,000 fallowed acres. For California tribal and Nevada tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with the **lowest level of impact** on acres of fallowed lands during a maximum shortage of 3.6 maf, with no change in fallowed acres. For Arizona tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on acres of fallowed lands during a maximum shortage of 3.6 maf, with an increase of about 67,000 fallowed acres.

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[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and social conditions associated with changes in agriculture due to water shortages *(continued)*	Level of annual impacts on market value of crop production from a maximum shortage	For Arizona non-tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on market value of crops during a maximum shortage of 0.6 maf, with a loss in market value of about $1.8 million.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the No Action Alternative is among the alternatives with the **lowest level of impact** on market value of crops during a maximum shortage of 0.6 maf, with no loss in market value. For Arizona tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on market value of crops during a maximum shortage of 0.6 maf, with a loss in market value of about $17.4 million.	For Arizona non-tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **low level of impact** on market value of crops during a maximum shortage of 1.5 maf, with a loss in market value of about $17.6 million.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with the **lowest level of impact** on market value of crops during a maximum shortage of 1.5 maf, with no change in market value. For Arizona tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 1.5 maf, with a loss in market value of about $82.3 million.	For Arizona non-tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **medium level of impact** on market value of crops during a maximum shortage of 3.0 maf, with a loss in market value of about $79.6 million. For California non-tribal, agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 3.0 maf, with a loss in market value of about $691.8 million. For California tribal and Nevada tribal agriculture entitlement holders, the Enhanced Coordination Alternative has the **highest level of impact** on market value of crops during a maximum shortage of 3.0 maf, with a loss in market value of about $10.9 million and $0.6 million, for California tribal and Nevada tribal agriculture entitlement holders, respectively. For Arizona tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **medium level of impact** on market value of crops during a maximum shortage of 3.0 maf, with a loss in market value of about $52.5 million.	For Arizona non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on market value of crops during a maximum shortage of 4.0 maf, with a loss in market value of about $150.8 million. For California non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on market value of crops during a maximum shortage of 4.0 maf, with a loss in market value of about $1,094.3 million. For California tribal and Nevada tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with the **lowest level of impact** on market value of crops during a maximum shortage of 4.0 maf, with no change in market value. For Arizona tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of** on market value of crops during a maximum shortage of 4.0 maf, with a loss in market value of about $113.2 million.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on market value of crops during a maximum shortage of 2.1 maf, with a loss in market value of about $21.0 million. For California non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on market value of crops during a maximum shortage of 2.1 maf, with a loss in market value of about $25.4 million. For California tribal and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with the **lowest level of impact** on market value of crops during a maximum shortage of 2.1 maf, with no change in market value. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 2.1 maf with a loss in market value of about $88.7 million.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **medium level of impact** on market value of crops during a maximum shortage of 2.1 maf, with a loss in market value of about $78.2 million. For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 2.1 maf, with a loss in market value of about $473.8 million, $7.7 million, and $0.5 million, for California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, respectively. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **medium level of impact** on market value of crops during a maximum shortage of 2.1 maf with a loss in market value of about $51.7 million.	For Arizona non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 3.6 maf, with a loss in market value of about $133.1 million. For California non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 3.6 maf, with a loss in market value of about $812.7 million. For California tribal and Nevada tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with the **lowest level of impact** on market value of crops during a maximum shortage of 3.6 maf, with no change in market value. For Arizona tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on market value of crops during a maximum shortage of 3.6 maf, with a loss in market value of about $111.9 million.

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[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and social conditions associated with changes in agriculture due to water shortages *(continued)*	Level of annual impacts on economic contributions, including jobs, labor income, and total economic output from a maximum shortage	For Arizona non-tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on economic contributions during a maximum shortage of 0.6 maf, with a loss of over 10 jobs, about $0.6 million in labor income, and $2.8 million in economic output.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the No Action Alternative is among the alternatives with the **lowest level of impact** on economic contributions during a maximum shortage of 0.6 maf, with no loss in jobs, labor income, or economic output. For Arizona tribal agriculture entitlement holders, the No Action Alternative has the **lowest level of impact** on economic contributions during a maximum shortage of 0.6 maf, with a loss of about 135 jobs, $10.7 million in labor income, and $34.8 million in economic output.	For Arizona non-tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **medium level of impact** on economic contributions during a maximum shortage of 1.5 maf, with a loss of about 135 jobs, $8.1 million in labor income, and $27.4 million in economic output.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with the **lowest level of impact** on economic contributions during a maximum shortage of 1.5 maf, with no change in jobs, labor income, or economic output. For Arizona tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 1.5 maf, with a loss of about 900 jobs, $48.1 million in labor income, and $162.2 million in economic output[4]	For Arizona non-tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 3.0 maf, with a loss of about 500 jobs, $29.0 million in labor income, and $126.8 million in economic output. For California non-tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 3.0 maf, with a loss of about 4,000 jobs, $246.5 million in labor income, and $1.0 billion in economic output. For California tribal and Nevada tribal agriculture entitlement holders, the Enhanced Coordination Alternative has the **highest level of impact** on economic contributions during a maximum shortage of 3.0 maf, with a loss of about 63 jobs, $3.9 million in labor income, and $15.9 million in economic output for California tribal entitlement holders, and a loss of about 13 jobs, $0.1 million in labor income, and $0.9 million in economic output for Nevada tribal agriculture entitlement holders. For Arizona tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 1.5 maf,	For Arizona non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on economic contributions during a maximum shortage of 4.0 maf, with a loss of about 1,000 jobs, $56.5 million in labor income, and $237.7 million in economic output. For California non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of impact** on economic contributions during a maximum shortage of 4.0 maf, with a loss of about 11,000 jobs, $824.7 million in labor income, and $1.8 billion in economic output. For California tribal and Nevada tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with the **lowest level of impact** on economic contributions during a maximum shortage of 4.0 maf, with no change in jobs, labor income, or economic output. For Arizona tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative has the **highest level of** on economic contributions during a maximum shortage of 1.5 maf, with a loss of about 1,000 jobs, $64.7 million in labor income, and $222.6 million in economic output.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **medium level of impact** on economic contributions during a maximum shortage of 2.1 maf, with a loss of about 160 jobs, $9.5 million in labor income, and $32.6 million in economic output. For California non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a low **level of impact** on economic contributions during a maximum shortage of 2.1 maf, with a loss of over 140 jobs, about $8.5 million in labor income, and $36.9 million in economic output. For California tribal and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with the **lowest level of impact** on economic contributions during a maximum shortage of 2.1 maf, with no change in jobs, labor income, or economic output. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 1.5 maf, with a loss of about 900 jobs, $51.3 million in labor income, and $174.6 million in economic output.	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 2.1 maf, with a loss of 500 jobs, about $28.4 million in labor income, and $124.3 million in economic output. For California non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 2.1 maf, with a loss of about 3,000 jobs, $173.4 million in labor income, and $689.2 million in economic output. For California tribal and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **low level of impact** on economic contributions during a maximum shortage of 2.1 maf, with a loss of about 45 jobs, $2.8 million in labor income, and $11.2 million in economic output for California tribal entitlement holders, and a loss of about 9 jobs, $0.1 million in labor income, and $0.6 million in economic output for Nevada tribal agriculture entitlement holders. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on economic contributions during a	For Arizona non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 3.6 maf, with a loss of 900 jobs, about $50.5 million in labor income, and $210.7 million in economic output. For California non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 3.6 maf, with a loss of 9,000 jobs, about $718.1 million in labor income, and $1.3 billion in economic output. For California tribal and Nevada tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with the **lowest level of impact** on economic contributions during a maximum shortage of 3.6 maf, with no change in jobs, labor income, or economic output. For Arizona tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on economic contributions during a maximum shortage of 3.6 maf, with a loss of 1,000 jobs, about $64.0 million in labor income, and $220.0 million in economic output.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and social conditions associated with changes in agriculture due to water shortages *(continued)*	*(see above)*	*(see above)*	*(see above)*	with a loss of about 500 jobs, $31.2 million in labor income, and $104.7 million in economic output.	*(see above)*	*(see above)*	maximum shortage of 1.5 maf, with a loss of about 400 jobs, $30.7 million in labor income, and $103.0 million in economic output.	*(see above)*
	Impacts on nonmarket values and social conditions from changes in agriculture	For non-tribal and tribal agriculture entitlement holders in Arizona, California, and Nevada, the No Action Alternative is among the alternatives with the **lowest level of impact** on access and quality of nonmarket values and social conditions due to the little to no increases in acreages of fallowed agriculture lands expected from shortages, under this alternative.[4]	For Arizona non-tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **low level of impact** on access and quality of nonmarket values and social conditions due to the low level of impact on acreages of fallowed agriculture lands from shortages.[4] For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with the **lowest level of impact** on access and quality of nonmarket values and social conditions due to the little to no increases in acreages of fallowed agriculture lands expected from shortages, under this alternative. For Arizona tribal agriculture entitlement holders, the Basic Coordination Alternative is among the alternatives with a **medium level of impact** on access and quality of nonmarket values and social conditions due to the medium level of impact on acreages of fallowed agriculture lands from shortages.	For Arizona non-tribal and tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **medium level of impact** on access and quality of nonmarket values and social conditions due to the medium level of impact on acreages of fallowed agriculture lands from shortages. For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Enhanced Coordination Alternative is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages.	For Arizona non-tribal and tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages. For California non-tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages. For California tribal and Nevada tribal agriculture entitlement holders, the Maximum Operational Flexibility Alternative is among the alternatives with the **lowest level of impact** on access and quality of nonmarket values and social conditions due to the little to no increases in acreages of	For Arizona non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on access and quality of nonmarket values and social conditions due to the low level of impact on acreages of fallowed agriculture lands from shortages. For California non-tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **low level of impact** on access and quality of nonmarket values and social conditions due to the low level of impact on acreages of fallowed agriculture lands from shortages. For California tribal and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with the **lowest level of impact** on access and quality of nonmarket values and social conditions due to the little to no increases in acreages of	For Arizona non-tribal and tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **medium level of impact** on access and quality of nonmarket values and social conditions due to the medium level of impact on acreages of fallowed agriculture lands from shortages. For California non-tribal, California tribal, and Nevada tribal agriculture entitlement holders, the Supply Driven Alternative (LB Pro Rata approach) is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages.	For Arizona non-tribal and tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages. For California non-tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages. For California tribal and Nevada tribal agriculture entitlement holders, the Representative Preferred Alternative is among the alternatives with the **lowest level of impact** on access and quality of nonmarket values and social conditions due to the little to no increases in acreages of fallowed agriculture lands expected from shortages, under this alternative.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and social conditions associated with changes in agriculture due to water shortages *(continued)*	*(see above)*	*(see above)*	*(see above)*	*(see above)*	fallowed agriculture lands expected from shortages, under this alternative.	fallowed agriculture lands expected from shortages, under this alternative. For Arizona tribal agriculture entitlement holders, the Supply Driven Alternative (LB Priority approach) is among the alternatives with a **high level of impact** on access and quality of nonmarket values and social conditions due to the high level of impact on acreages of fallowed agriculture lands from shortages.	*(see above)*	*(see above)*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.
[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	**Basic Coordination Alternative**	**Enhanced Coordination Alternative**	**Maximum Operational Flexibility Alternative**	**Supply Driven Alternative (LB Priority)**	**Supply Driven Alternative (LB Pro Rata)**	**Representative Preferred**
Economic contributions and value associated with Lake-Based Recreation	Changes in recreation visitor spending and associated regional employment, labor income, and total economic output from lake-based recreation-related activities	Under No Action and all Action Alternatives, declining reservoir elevations at Lake Powell and Lake Mead reduce access to boating, marina operations, and shoreline recreation in dry conditions. This is expected to lead to a decrease in visitation and associated spending on lodging, food services, and transportation-related spending in nearby gateway communities. Businesses that rely on water-based visitation, including marinas, guide services, motels, and equipment rentals, are expected to experience losses in jobs and labor income. Downstream economic effects also weaken, reducing Potential for overall economic output.	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. For Lake Powell, economic contributions associated with recreational use are likely to be similar to existing conditions For Lake Mead, there is more robust performance related to recreation site access and navigation thresholds, therefore visitation and spending associated with this reservoir are anticipated to be maintained at levels at or above that of the No Action Alternative.	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. This alternative is among the most robust in terms of meeting thresholds for navigation in Lake Powell, and recreation access and Lake Mead. Consequently, Employment and income losses remain but occur at lower levels relative to No Action and Basic Coordination Alternatives. Gateway communities experience more consistent seasonal activity.	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. As discussed under for the Maximum Operational Flexibility Alternative, consequently, economic contributions from lake-based recreation would likely be higher than the CCS Comparative Baseline and No Action Alternative due to more robust maintenance of access for recreation sites and navigation Consequently Employment and income losses remain but occur at lower levels relative to No Action and Basic Coordination Alternatives. Gateway communities experience more consistent seasonal activity.	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. For Lake Powell recreation site and navigation access would be less robust than the No Action Alternative which could further impact recreational spending and gateway businesses and concessionaire associated with Lake Powell. In contrast, for Lake Mead, the Supply Driven Alternative (LB Priority approach) modeling represents the most robust outcomes for recreation site access and navigation, supporting continued or increased spending associated with recreation activities for this reservoir.	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. Impacts would be the same as described for the Supply Driven Alternative (LB Priority approach).	Decreases in visitation and associated spending would occur under dry conditions as described under the No Action Alternative. On Lake Powell, the Representative Preferred would be slightly more robust in terms of maintenance of critical thresholds for navigation than the No Action Alternative and CCS Comparative Baseline. Compared to other action alternatives, this is better than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), but less robust than the Enhanced Coordination and Maximum Operational Flexibility Alternatives in terms of support for recreational spending. For reservoir-based recreation on Lake Mead, the Representative Preferred modeling represents less robust outcomes for recreational site access as compared to the CCS Comparative Baseline but slightly more robust outcomes than the No Action Alternative This is a similar level of performance to the other action alternatives. For navigation, the Representative Preferred Alternative is more robust at meeting defined thresholds than both the No Action and CCS Comparative Baseline.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred
Economic contributions and value associated with Lake-Based Recreation *(continued)*	*(see above)*	*(see above)*	*(see above)*	*(see above)*	*(see above)*	*(see above)*	*(see above)*	Overall, recreational spending and gateway businesses and concessionaire associated with Lake Mead would be similar to other action alternatives.
	Percent of modeled futures in which *the annual recreational value[5] of whitewater boating exceeds 32 million dollars at least 90% of years* over the first decadal period. This threshold indicates when modeled futures achieve recreation values at least as high as the lowest 10% of outcomes for recreation value based on recent historic hydrologic data (2020-2023).	**60%** of modeled futures meet *the preferred minimum performance.*	**78%** of modeled futures meet *the preferred minimum performance.*	**18%** of modeled futures meet *the preferred minimum performance.*	**36%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**38%** of modeled futures meet *the preferred minimum performance.*	**37%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[5] Recreational value of whitewater boating is calculated based on net economic value changes for whitewater rafting in Grand Canyon. This approach follows the methods used in the Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement, where past survey research (Neher et al. 2017, Bishop et al. 1987) informed models to project the change in net economic value under different river flow scenarios. These models link willingness-to-pay estimates for boaters to hydrologic conditions, providing a measure of recreation benefits that extends beyond market spending. Reclamation used similar methods for the analysis of potential impacts on recreation as were used in the 2007 Final EIS and 2024 Near-term Colorado River Operations Final Supplemental Environmental Impact Statement (2024 Final SEIS) to assess the effects on recreation value associated with white-water boating.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Economic contributions and value associated with Lake-Based and River-based Recreation *(continued)*	Percent of modeled futures in which *the annual recreational value[6] of angling exceeds 1.75 million dollars in at least 90% of years* over the first decadal period. This value indicates when modeled futures achieve recreation values at least as high as the lowest 10% of outcomes for recreation value based on recent historic hydrologic data (2020-2023).	**40%** of modeled futures meet *the preferred minimum performance.*	**63%** of modeled futures meet *the preferred minimum performance.*	**2%** of modeled futures meet *the preferred minimum performance.*	**19%** of modeled futures meet *the preferred minimum performance.*	**34%** of modeled futures meet *the preferred minimum performance.*	**34%** of modeled futures meet *the preferred minimum performance.*	**9%** of modeled futures meet *the preferred minimum performance.*

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[6] Recreational value of angling is calculated based on net economic value changes for angling in Glen Canyon. This approach follows the methods used in the Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement, where past survey research (Neher et al. 2017, Bishop et al. 1987) informed models to project the change in net economic value under different river flow scenarios. These models link willingness-to-pay estimates for boaters to hydrologic conditions, providing a measure of recreation benefits that extends beyond market spending. Reclamation used similar methods for the analysis of potential impacts on recreation as were used in the 2007 Final EIS and 2024 Final SEIS to assess the effects on recreation value associated with angling.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
How would anticipated water shortages and changes in water levels in reservoirs and river segments affect access and quality of nonmarket values?	Changes in existence and symbolic values of the river due to shifts in scenic character or ecological conditions.	Lower reservoir elevations and increased shoreline exposure reduce opportunities for solitude, as well as access to quiet coves, beaches, and natural shorelines. These conditions diminish the experiential qualities that many users value. Extended low-flow periods could also impact river-based experiences in Grand Canyon due to changes in setting which could impact perceived naturalness (see **TA 14, Recreation**). Cultural and spiritual values tied to iconic landscapes and cultural artifacts could also be impacted in low-hydrologic flow periods (see **TA 11, Cultural Resources**). Ecological services such as riparian habitat stability may decline, influencing non-use values related to wildlife and vegetation communities (see **TA 8, Biological Resources – Fish and Other Aquatic Resources**).	Under dry conditions nonmarket values could be impacted as discussed under the no action alternative. More frequent low-elevation conditions could occur in the Basic Coordination Alternative, which could noticeably affect nonmarket values tied to lake-based recreation and scenic quality (see **TA 14, Recreation**) although at a reduced level compared to the No Action Alternative. Reduced reservoir levels may expose previously submerged areas, altering visual character and diminishing opportunities for solitude. Overall impacts are similar to the No Action.	Under dry conditions nonmarket values could be impacted as discussed under the no action alternative. The Enhanced Coordination Alternative is more robust in terms of the support for nonmarket values, particularly for values associated with Lake Powell, as reservoir levels would be maintained at thresholds supporting access for boating and camping in more modeled futures, supporting experiential benefits and cultural connections (see **TA 11, Cultural Resources**). River-based recreation quality is expected to remain high, due to increased stability with flow-dependent activities (see **TA 14, Recreation**). Non-use values tied to ecosystem services, such as wildlife habitat and riparian vegetation, would also be supported (see **TA 8, Biological Resources – Fish and Other Aquatic Resources**).	Under dry conditions nonmarket values could be impacted as discussed under the no action alternative. Similar to the Enhanced Coordination Alternative, this alternative is more robust in terms of the support for nonmarket values, particularly for values associated with Lake Powell, and for river Based recreation, due to increased stability with flow-dependent activities (see **TA 14, Recreation**).	Outcomes produced by the Supply Driven Alternative (LB Priority approach) vary depending on hydrology and location. In wet years, nonmarket values remain similar to the No Action Alternative but in dry sequences, reduced reservoir elevations and altered flow regimes diminish scenic quality and access for boating and angling (see **TA 14, Recreation**), for Lake Powell. For Lake Mead, the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the most robust for supporting reservoir levels at Lake Mead which support non-market values. River-based recreation experiences moderate variability in trip quality, while ecosystem services and associated non-use values fluctuate with water availability (see **TA 8, Biological Resources – Fish and Other Aquatic Resources**). Cultural and spiritual values tied to river corridors may also be affected during extended drought periods (see **TA 11, Cultural Resources**).	Impacts would be as described for the Supply Driven Alternative (LB Priority approach).	Under dry conditions nonmarket values could be impacted as discussed under the no action alternative. For values associated with lake-based recreation, modeled results show reduced low-elevation outcomes in Lake Powell and Mead compared to more vulnerable alternatives, but vulnerability remains under drier future hydrologic conditions (**TA 3, Hydrology**). The Representative Preferred Alternative generally performs in the middle of the range of alternatives for both Lake Powell and Lake Mead elevations as well as river flow, showing moderate robustness in terms of overall support for recreation associated benefits (**TA 14, Recreation**). Overall, this alternative would provide moderate protection for riverine habitat to support cultural values (see TA 13, Tribal). The preferred alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in Chapter 2, as a result, impacts for any given sub-period in the planning period may differ from those described.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Population and Land Use (See Section 3.17)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Priority Group: Arizona Central Arizona Project (CAP) non-Indian agriculture (NIA)-A and NIA-B	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**0%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
	Percent of modeled futures in which greater than 60% of normal delivery occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**0%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
Priority Group: Arizona CAP Indian, municipal and industrial (M&I), and 4(i)	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**13%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
Priority Group: Arizona Priorities 2 and 3	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**26%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**54%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**35%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**58%** of modeled futures meet the performance definition.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.
[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.
[7] Normal delivery refers to a full supply of domestic water delivery throughout this table.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Priority Group: Arizona present perfected right (PPR)	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.
Priority Group: California Priority 4	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.
[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.
[7] Normal delivery refers to a full supply of domestic water delivery throughout this table.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Priority Group: California PPR	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.
Priority Group: Nevada Priorities 1-7	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**18%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.
[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.
[7] Normal delivery refers to a full supply of domestic water delivery throughout this table.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Priority Group: Nevada Priority 8	Percent of modeled futures in which greater than 80% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.[4]	**0%** of modeled futures meet the performance definition.	**1%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.	**18%** of modeled futures meet the performance definition.	**0%** of modeled futures meet the performance definition.
	Percent of modeled futures, in which greater than 60% of normal domestic delivery[7] occurs at least 90% of years, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.[4]	**100%** of modeled futures meet the performance definition.	**22%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**100%** of modeled futures meet the performance definition.	**54%** of modeled futures meet the performance definition.
Lower Basin Domestic Water Deliveries	Percent of modeled futures in which dead pool-related delivery reductions occur, across the first decade of the modeling period (2027 – 2039)	**59%** of modeled futures with dead pool-related reductions	**32%** of modeled futures with dead pool-related reductions	**12%** of modeled futures with dead pool-related reductions	**6%** of modeled futures with dead pool-related reductions	**23%** of modeled futures with dead pool-related reductions	**12%** of modeled futures with dead pool-related reductions	**8%** of modeled futures with dead pool-related reductions

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[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.
[7] Normal delivery refers to a full supply of domestic water delivery throughout this table.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Comparison of impacts on senior and junior entitlements	Shortage to domestic water users, across the first decade of the modeling period	>80% of normal domestic water delivery to senior entitlements (Arizona (AZ) P2 & P3; AZ PPR; California (CA) PPR; and Nevada (NV) P1-7 priority groups) and some junior entitlements (CA P4 and NV P8 priority groups) occurs in all potential futures. In contrast, for Arizona junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i) priority groups) there are no potential futures in which >80% normal domestic water delivery occurs.[4] AZ CAP Indian, M&I, and 4(i) receives >60% of normal domestic water delivery in all potential futures There are no potential futures in which Arizona CAP NIA-A and NIA-B priorities receive any percentage of normal domestic water delivery. While this alternative results in all senior priority groups and some Arizona, California, and Nevada junior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to Arizona CAP NIA-A and NIA-B.	>80% of normal domestic water delivery to senior entitlements (AZ P2 & P3; AZ PPR; CA PPR; and NV P1-7 priority groups) and some junior entitlements (CA P4 priority group) occurs in all potential futures. In contrast, for Arizona and Nevada junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); and NV P8 priority groups) there are no potential futures in which >80% normal domestic water delivery occurs.[4] NV P8 receives >60% of normal domestic water delivery in all potential futures. There are no potential futures in which Arizona junior priority receive any percentage of normal domestic water delivery. While this alternative results in all senior priority groups and some California junior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to Arizona junior priority groups.	>60% of normal domestic water delivery to all Arizona, California, and Nevada priority groups occurs in all potential futures. While this alternative results in more priority groups receiving domestic water delivery closer to normal conditions, it results in domestic shortage impacts on Arizona, California, and Nevada senior entitlements that would otherwise receive domestic water deliveries consistent with normal conditions.	>80% of normal domestic water delivery to some senior priority groups (AZ PPR; CA PPR; and NV P1-7 priority groups) occurs in all potential futures. In contrast, for all Arizona, California, and Nevada junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); CA P4; and NV P8 priority groups) there are no potential futures, in which >80% of normal domestic water delivery occurs. AZ P2 & P3 receives >60% and >80% of normal delivery in 26% and 35% of potential futures, respectively. NV P8 receives >60% and >80% of normal domestic water delivery in 1% and 22% of potential futures, respectively. There are no potential futures in which Arizona and California junior entitlements receive any percentage of normal domestic water delivery. While this alternative results in Arizona and California PPR and Nevada senior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to all Arizona and California junior priority groups.	>80% of normal domestic delivery to some senior entitlements (AZ P2 & P3; AZ PPR; CA PPR; and NV P1-7 priority groups) occurs in all potential futures. In contrast, for junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and4(i); CA P4; and NV P8 priority groups), there are no potential futures, in which >80% of normal domestic water delivery occurs. NV P8 receives >60% of normal domestic water delivery in all potential futures. AZ CAP Indian, M&I, and 4 (i) receives >20% of normal domestic water delivery in 31-40% of potential futures. There are no potential futures in which Arizona CAP NIA-A and NIA-B and CA P4 priority groups receive any percentage of normal domestic water delivery. While this alternative results in all senior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to some Arizona and California junior priority groups.	>80% normal domestic water delivery occurs in all potential futures for all California priority groups. >60% of normal domestic delivery to all Arizona and Nevada priority groups occurs in all potential futures. While this alternative results in more Arizona junior priority groups receiving domestic delivery closer to normal conditions, it results in domestic shortage impacts on Arizona and Nevada senior entitlements that would otherwise receive deliveries consistent with normal conditions.	>80% of normal domestic water delivery to some senior priority groups (AZ PPR; CA PPR; and NV P1-7 priority groups) occurs in all potential futures. In contrast, for all Arizona, California, and Nevada junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); CA P4; and NV P8 priority groups) there are no potential futures, in which >80% of normal domestic water delivery occurs. AZ P2 & P3 receives >60% and >80% of normal delivery in 54% and 58% of potential futures, respectively. NV P8 receives >60% and >80% of normal domestic water delivery in 0% and 51% of potential futures, respectively. There are no potential futures in which Arizona and California junior entitlements receive any percentage of normal domestic water delivery. While this alternative results in Arizona and California PPR and Nevada senior priority groups receiving domestic water delivery closest to normal conditions, it results in domestic shortage impacts to all Arizona and California junior priority groups.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
How would operational changes affect irrigated agricultural land?	Acres of irrigated agricultural land within the analysis area and potential for changes based on agricultural water availability	Frequent and severe shortages for junior-priority irrigation users likely lead to fallowing, crop switching, and long-term land retirement in Arizona counties (La Paz, Mohave and Yuma); Imperial Valley impacts are more limited.	Concentrated impacts for junior users in Arizona still drive significant agricultural land use changes; California and senior priority holders see limited more limited impacts	Pro rata distribution mitigates concentrated impacts for junior users but introduces broader reductions, increasing risk of widespread crop switching and fallowing in both Arizona and California.	Large shortage volumes and reliance on conservation participation create high uncertainty; potential for extensive land retirement if participation is low.	Concentrates impacts on junior users, preserving senior districts but accelerating land use change in Arizona counties (La Paz, Mohave and Yuma).	Distributes shortages broadly, increasing exposure for senior priority holders California and potentially leading to widespread fallowing and crop switching across the Basin.	The representative preferred alternative for 2027-2028 would result in shortages, with impacts concentrated on junior users. In the longer term (2029-2060) modeled outcomes indicate potential for additional fallowing land and crop switching, with impacts concentrated on junior users. However, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative, as a result, the potential for fallowing, crop switching, and other associated long term land - use patterns in any given area may vary and impacts may be mitigated in part by specific operational guidelines

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Indian Trust Assets (See Section 3.18)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Upper Basin Tribal Water Deliveries	Typical Water Deliveries	The alternatives act the same in terms of Upper Basin tribal water deliveries.						
Lower Basin Tribal Water Deliveries	Percent of modeled futures in which *dead pool-related delivery reductions never occur in 2027-2039*	**41%** of modeled futures do not have dead pool-related reductions.	**68%** of modeled futures do not have dead pool-related reductions.	**88%** of modeled futures do not have dead pool-related reductions.	**94%** of modeled do not have dead pool-related reductions.	**77%** of modeled futures do not have dead pool-related reductions.	**88%** of modeled futures do not have dead pool-related reductions.	**95%** of modeled futures do not have dead pool-related reductions.
Lower Basin Tribal Water Deliveries (Group of tribes with PPR rights)	At least 80% of Normal Water Deliveries (i.e., non-shortage conditions) occurs in at least 90% of years across 2027-2039. The higher the percentage, the more frequently deliveries are estimated to remain consistent with normal delivery.	**100%** of modeled futures meet the minimum preferred performance.[4]	**100%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.	**100%** of modeled futures meet the minimum preferred performance.	**100%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**100%** of modeled futures meet the minimum preferred performance.
Lower Basin Tribal Water Deliveries (Group of tribes with AZ Priority 3 entitlements)	At least 80% of Normal Water Deliveries (i.e., non-shortage conditions) occurs in at least 90% of years across 2037-2039. The higher the percentage, the more frequently deliveries are estimated to remain consistent with normal delivery.	**100%** of modeled futures meet the minimum preferred performance.[4]	**100%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.	**60%** of modeled futures meet the minimum preferred performance.	**100%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**65%** of modeled futures meet the minimum preferred performance.
Lower Basin Tribal Water Deliveries (Group of tribes with Arizona CAP Indian, M&I, and 4i entitlements)	At least 80% of Normal Water Deliveries (i.e., non-shortage conditions) occurs in at least 90% of years across 2037-2039. The higher the percentage, the more frequently deliveries are estimated to remain consistent with normal delivery.	**100%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.
Lower Basin Tribal Water Deliveries (Group of tribes with Arizona CAP Non-Indian Agriculture entitlements)	At least 80% of Normal Water Deliveries (i.e., non-shortage conditions) occurs in at least 90% of years across 2037-2039. The higher the percentage, the more frequently deliveries are estimated to remain consistent with normal delivery.	**0%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.[4]	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.	**0%** of modeled futures meet the minimum preferred performance.
Trust Land (Arizona)	Acres of Fallowed Tribal Land	12,419 [4]	12,419 to 49,582 [4]	8,067 to 39,200	6,535 to 68,054	6,535 to 53,560	15,794 to 38,605	6,535 to 67,375 [4]
Trust Land (California)	Acres of Fallowed Tribal Land	0 [4]	0 [4]	1,298 to 5,092	0	0	579 to 2,803	0 [4]
Trust Land (Nevada)	Acres of Fallowed Tribal Land	0 [4]	0 [4]	131 to 656	0	0	131 to 460	0 [4]

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

[4] Note that these impacts are based on low maximum Lower Basin shortage volumes that translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**), which could result in significant but highly uncertain impacts.

Visual Resources (See Section 3.19)

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Visibility of Attraction Features	Percent of futures in which *Lake Powell elevation is below 3,550 feet in at least 90% of months*. The higher the percentage, the more likely Lake Powell will remain at elevations where Cathedral in the Desert is visible and accessible.	**82%** of modeled futures meet *the preferred minimum performance*. **Most acceptable** futures where Cathedral in the Desert is visible and accessible.	**78%** of modeled futures meet *the preferred minimum performance*. **Second most acceptable** futures where Cathedral in the Desert is visible and accessible.	**52%** of modeled futures meet *the preferred minimum performance*. **Fewest acceptable** futures where Cathedral in the Desert is visible and accessible.	**59%** of modeled futures meet *the preferred minimum performance*. **Second fewest** acceptable futures where Cathedral in the Desert is visible and accessible.	**77%** of modeled futures meet *the preferred minimum performance*. **Third most acceptable futures** where Cathedral in the Desert is visible and accessible.		**75%** of modeled futures meet *the preferred minimum performance*. **Fourth most acceptable futures** where Cathedral in the Desert is visible and accessible.
	Percent of futures in which *Lake Powell elevation is above 3,550 feet at least 90% of months*. The higher the percentage, the more likely less of Glen Canyon Dam will be visible. Hoover Dam visibility is based on modeling associated with the next issue statement.	**18%** of modeled futures meet *the preferred minimum performance*. **Fewest** futures where less of Glen Canyon and Hoover dams would be visible, with their increased visibility further dominating the local landscape character.	**22%** of modeled futures meet *the preferred minimum performance*. **Second fewest** futures where less of Glen Canyon Dam would be visible, with its increased visibility further dominating the local landscape character with less of Hoover Dam visible compared to the No Action.	**48%** of modeled futures meet *the preferred minimum performance*. **Most acceptable futures** where less of Glen Canyon and Hoover dams would be visible, reducing their level of dominance in the local landscape compared to the No Action	**41%** of modeled futures meet *the preferred minimum performance*. **Second most acceptable** futures where less of Glen Canyon and Hoover dams would be visible, reducing their level of dominance in the local landscape compared to the No Action.	**23%** of modeled futures meet *the preferred minimum performance*. **Third fewest** futures where less of Glen Canyon Dam would be visible, with its increased visibility further dominating the local landscape character. Based on managing higher reservoir levels in Lake Mead compared to Lake Powell under this alternative, less of the upstream side of Hoover Dam would be visible under this alternative (similar to the Enhanced Coordination and Maximum Flexibility alternatives) with comparatively more of the upstream side of Glen Canyon Dam being visible as described above.		**25%** of modeled futures meet *the preferred minimum performance*. **Third most** futures where less of Glen Canyon Dam would be visible, with its increased visibility further dominating the local landscape character with less of Hoover Dam visible compared to the No Action.

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Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Lake Powell and Lake Mead landscape character	Percent of futures in which ***Lake Powell*** *elevation would result in calcium carbonate rings remaining under historic maximums for 100% of the modeling period*. Based on updated modeling, the analysis focused on a threshold of 200 feet instead of the historic maximum. The higher the percentage, the more likely calcium carbonate rings at Lake Powell will remain shorter than historic maximums.	**4%** of modeled futures meet *the preferred minimum performance*.	**19%** of modeled futures meet *the preferred minimum performance*.	**81%** of modeled futures meet *the preferred minimum performance*.	**94%** of modeled futures meet *the preferred minimum performance*.	**35%** of modeled futures meet *the preferred minimum performance*.		**45%** of modeled futures meet *the preferred minimum performance*.
	Percent of futures in which ***Lake Mead*** *elevation would result in calcium carbonate rings remaining under historic maximums for 100% of the modeling period*. Based on updated modeling, the analysis focused on a threshold of 200 feet instead of the historic maximum. The higher the percentage, the more likely calcium carbonate rings at Lake Mead will remain shorter than historic maximums.	**8%** of modeled futures meet *the preferred minimum performance*.	**20%** of modeled futures meet *the preferred minimum performance*.	**17%** of modeled futures meet *the preferred minimum performance*.	**22%** of modeled futures meet *the preferred minimum performance*.	**44%** of modeled futures meet *the preferred minimum performance*.		**23%** of modeled futures meet *the preferred minimum performance*.
Colorado River landscape character	Qualitative description of the effect associated with proposed flow rates and the potential to conduct HFEs from Glen Canyon Dam under each alternative.	Initially, there would be less impacts as flows would remain above 7.0 maf; however, if Lake Powell reaches dead pool, impacts would be extensive and immediate due to a dramatic reduction in flows. The current trends of increasing bank armoring, associated with expanding riparian vegetation areas (including tamarisk), would continue under the No Action Alternative. This alternative has the **fewest futures** where HFEs are conducted during the full modeling period.	Impacts would be similar to the No Action since it includes a similar range of releases from Glen Canyon Dam. This alternative would have an **increased number of futures** where HFEs are conducted compared to the No Action Alternative.	Based on yearly projections, if releases as low as 4.7 maf are needed, there would be increased impacts on the river's landscape character. If releases are above 7.0 maf, impacts would be the same as the No Action Alternative. This alternative would result in the **second most futures** where HFEs are conducted.	Based on yearly projections, if releases as low as 5.0 maf are needed, there would be increased impacts on the river's landscape character. If releases are above 7.0 maf, impacts would be the same as the No Action Alternative. This alternative would result in the **most futures** where HFEs are conducted.	Based on yearly projections, if releases as low as 4.7 maf are needed, there would be increased impacts on the river's landscape character. If releases are above 7.0 maf, impacts would be the same as the No Action Alternative. This alternative has the **second fewest futures** where HFEs are conducted during the full modeling period.		Based on yearly projections, if releases as low as 6.0 maf are needed, there would be increased impacts on the river's landscape character. If releases are above 7.0 maf, impacts would be the same as the No Action Alternative. This alternative has the **second fewest futures** where HFEs are conducted during the full modeling period similar to the Supply Driven Alternative.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

Impact Category	Performance Indicator[1]	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority)	Supply Driven Alternative (LB Pro Rata)	Representative Preferred Alternative
Lower Division States' landscape character	Qualitative description of the effects associated with potential decreases in water availability for the Lower Division States on the broader landscape character including the potential to reach dead pool.	Initially, there would be lower impacts; however, if Lake Mead reaches dead pool, dramatic decreases in water availability could affect the landscape character in all three Lower Division States. Depending on the duration of these decreased water deliveries, the character of irrigated and agricultural landscapes within the Lower Division States would be modified through aridification of these areas; this would diminish the vivid greens associated with crops and ornamental plantings. This alternative has the **most futures** where dead pool shortage is reached.	Impacts would be similar to the No Action except this alternative includes increased shortages to Arizona and Nevada (up to 1.48 maf). While the potential to reach dead pool is reduced under this alternative, compared to the No Action Alternative, there is still a risk to reach dead pool under some futures. This alternative has the **second most futures** where dead pool shortage is reached.	Shortages up to 3.0 maf are possible under this alternative, which would incrementally affect all three Lower Division States including irrigated and agricultural landscapes. These shortages are designed to avoid reaching dead pool, tempering the impacts on the character of irrigated and agricultural landscapes within the Lower Division States and avoid more extensive impacts if Lake Mead reached dead pool. This alternative has the **second fewest** futures where dead pool shortage is reached.	Shortages up to 4.0 maf are possible under this alternative, which would incrementally affect all three Lower Division States including irrigated and agricultural landscapes. The shortages are designed to avoid reaching dead pool. This alternative has the **fewest futures** where dead pool shortage is reached.	Shortages up to 2.1 maf are possible under this alternative, which would incrementally affect all three Lower Division States including irrigated and agricultural landscapes. The shortages are designed to avoid reaching dead pool. This alternative, similar to the Enhanced Coordination Alternative, has the **second fewest futures** where dead pool shortage is reached.		Shortages up to 3.0 maf are possible under this alternative, which would incrementally affect all three Lower Division States including irrigated and agricultural landscapes. The shortages are designed to avoid reaching dead pool. This alternative, similar to the Enhanced Coordination Alternative, has the **second fewest futures** where dead pool shortage is reached.

[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

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[1] Some performance indicator descriptions include italics to denote a definition of the "*preferred minimum performance*" that was used as a significant reference point for technical analysis. The following were considered when determining preferred minimum performance: input from resource experts, the severity of negative outcomes associated with not satisfying a given performance level, historical (observed) data, and/or reasonably expected outcomes if current operations and recent hydrology continued. To find more information about preferred minimum performance levels, see Volume III – Technical Appendices.

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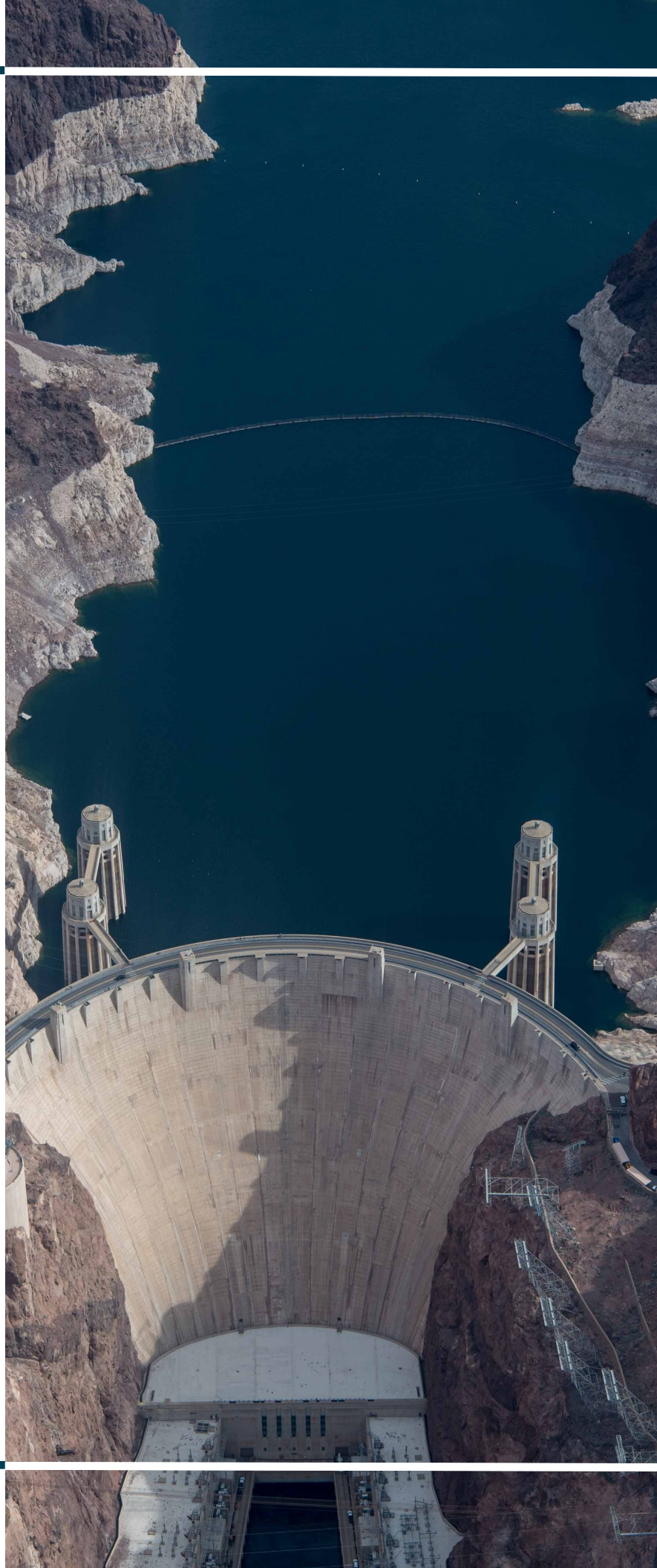
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BUREAU OF
RECLAMATION

Final Environmental Impact Statement

Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

Volume I: Main Body



July 2026
U.S. Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Basins
Interior Regions 7 and 8

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RECLAMATION

Mission Statements

The **Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo: Alexander Stephens / Bureau of Reclamation, 2018

Post-2026 Colorado River Reservoir Operations Final Environmental Impact Statement

Lead Agency:

United States Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Regions

Cooperating Agencies:

Bureau of Indian Affairs
National Park Service
United States Fish and Wildlife Service
United States Section of the International Boundary and Water Commission
Western Area Power Administration

Abstract:

The Secretary of the Department of the Interior, acting through the Bureau of Reclamation, proposes the adoption of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating range to take effect when the current agreements expire in 2026. Management strategies will primarily focus on the operation of Glen Canyon Dam and Hoover Dam, but may include actions upstream and downstream of these facilities to protect critical reservoir elevations. This Final EIS has been prepared to inform the Secretary's timely adoption of a new set of guidelines that would be sufficiently robust and provide improved predictability to all water users and managers in the Colorado River Basin.

This Final EIS has been prepared pursuant to the National Environmental Policy Act to address the formulation and evaluation of specific interim criteria and to identify the potential environmental impacts of implementing such criteria.

For further information regarding this Final EIS, contact:

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Filing Date: July 27, 2026

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
1944 Water Treaty	United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2006 Flaming Gorge Dam ROD	2006 Record of Decision for the Operation of Flaming Gorge Dam Final Environmental Impact Statement
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2007 ROD	2007 Interim Guidelines Record of Decision
2012 Aspinall ROD	2012 Record of Decision for the Aspinall Unit Operations Final Environmental Impact Statement
µg/L	micrograms per liter
afy	acre-feet per year
AAC	All-American Canal
ADM	Alternative Distribution Model
ADWR	Arizona Department of Water Resources
AOP	Annual Operating Plan for Colorado River Reservoirs
APE	area of potential effects
AZGFD	Arizona Game and Fish Department
Basin	Colorado River Basin
Basin Fund	Upper Colorado River Basin Fund
Basin States	Colorado River Basin States
BCPA	Boulder Canyon Project Act of 1928
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BO	Biological Opinion
BWSCP	Binational Water Scarcity Contingency Plan
°C	degrees Celsius
CAA	Clean Air Act
CAP	Central Arizona Project
CCS	Continued Current Strategies
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent

Compact	Colorado River Compact of 1922
Consolidated Decree	Consolidated Decree entered by the U.S. Supreme Court in the case of *Arizona v. California*, 547 U.S. 150 (2006)
CRBPA	Colorado River Basin Project Act of 1968
CRSP	Colorado River Storage Project
CRSPA	Colorado River Storage Project Act of 1956
CRiSPPy	Colorado River Storage Project Python model
CRSS	Colorado River Simulation System
CY	calendar year
CVWD	Coachella Valley Water District
Dam Fund	Colorado River Dam Fund
DCP	Drought Contingency Plan
Decree	1964 United States Supreme Court Decree in *Arizona v. California*
Department	Department of the Interior
Development Fund	Colorado River Basin Development Fund
DMDU	Decision Making under Deep Uncertainty
Draft EIS	Draft Environmental Impact Statement
DROA	Drought Response Operations Agreement
eGRID	Emissions and Generation Resource Integrated Database
EIS	environmental impact statement
EOCY	end of calendar year
EOWY	end of water year
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act of 1973
FWS	United States Fish and Wildlife Service
GCMRC	Grand Canyon Monitoring and Research Center
GCNP	Grand Canyon National Park
GDP	gross domestic product
GIS	geographic information system
GTMax	Generation and Transmission Maximization
HAP	Hazardous Air Pollutant
HCP	Habitat Conservation Plan
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HFE	High-Flow Experiment
ICS	intentionally created surplus
IID	Imperial Irrigation District
IMPLAN	Impact Analysis for Planning
Indian	American Indians
ISG	Interim Surplus Guidelines
IPaC	Information for Planning and Consultation
ITA	Indian trust asset

°F	degrees Fahrenheit
kaf	thousand acre-feet
kafy	thousand acre-feet per year
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LROC	Long-Range Operating Criteria (Criteria for Coordinated Long-Range Operation of the Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968)
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
mafy	million acre-feet per year
M&I	municipal and industrial
Mexico	United Mexican States
mg/L	milligrams per liter
msl	mean sea level
MW	megawatts
MWD	Metropolitan Water District of Southern California
MWh	megawatt hours
NAAQS	National Ambient Air Quality Standards
NDEP	Nevada Division of Environmental Protection
NDOW	Nevada Department of Wildlife
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act of 1969
NHA	National Heritage Area
NHL	National Historic Landmark
NHT	National Historic Trail
NIA	non-Indian agriculture
NIB	Northerly International Boundary
NOA	Notice of Availability
NOI	Notice of Intent
NPS	National Park Service
NRA	National Recreation Area
NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
O_3	Ozone
PFAS	per- and polyfluoroalkyl substances
PFYC	Potential Fossil Yield Classification
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
PPR	present perfected right
PRPA	Paleontological Resource Protection Act

PSD	Prevention of Significant Deterioration
PYFC	Potential Fossil Yield Classification
Reclamation	Bureau of Reclamation
RM	river mile
ROD	Record of Decision
SAM	Shortage Allocation Model
Secretary	Secretary of the Interior
SEIS	supplemental environment impact statement
Service	United States Fish and Wildlife Service
SHPO	State Historic Preservation Office
SIB	Southerly International Boundary
SIRA	Storage and Interstate Release Agreements
SNWA	Southern Nevada Water Authority
SSMP	Salton Sea Management Plan
TCP	traditional cultural property
U.S.	United States
USACE	United States Army Corps of Engineers
USC	United States Code
USGS	United States Geological Survey
USIBWC	United States Section of the International Boundary and Water Commission
WAPA	Western Area Power Association
WY	water year

Chapter 1. Purpose and Need

1.1 Introduction

The Colorado River Basin (Basin) provides essential water supplies to approximately 40 million people, nearly 5.5 million acres of agricultural lands, and habitat for ecological resources across seven states which includes broad areas in the Southwestern United States and Northwestern United Mexican States (Mexico) (**Map 1-1**). Prudent management of the Basin is critically important because the Colorado River is the foundation for diverse resources across a large geographic region and faces exceptional challenges from prolonged drought and future uncertainty. States, tribes, and Mexico rely on the Colorado River to support essential municipal, agricultural, environmental, cultural, and hydropower needs. These resources are now at significant risk: since the onset of the current drought in 2000, the Basin's primary reservoirs, Lake Powell and Lake Mead, have fallen to historically low elevations. Several of the major reservoir- and water-management documents and agreements developed to guide Colorado River operations through the persistently dry conditions expire in 2026, including the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines; Reclamation 2007a), the 2019 Colorado River Drought Contingency Plans (DCP; Reclamation 2019), and key international agreements between the United States and Mexico.[1] Despite the significance of these agreements, actions taken over the past two decades have not been sufficiently robust to prevent continued decline of the reservoirs through the prolonged drought.

The 2007 Interim Guidelines have provided operating criteria for Lake Powell and Lake Mead, including provisions designed to provide Colorado River water users, particularly those in the Lower Division States, a greater degree of predictability with respect to the timing and volumes of potential water delivery reductions, as well as additional operating flexibility to conserve and enhance water storage in Lake Mead. The 2007 Interim Guidelines were adopted for a limited period ("interim") to provide an opportunity for the Bureau of Reclamation (Reclamation) and interested entities to gain valuable experience in the management of Lake Powell and Lake Mead under modified operations, with the goal of improving the analytical basis for making future operational decisions, whether during the interim period or after. The valuable experience managing Lake Powell and Lake Mead gained since the adoption of the 2007 Interim Guidelines has informed important considerations in developing new guidelines for the post-2026 period.

The Secretary of the Interior (Secretary), acting through Reclamation, proposes adoption of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating ranges to take effect when the current agreements expire in 2026. Management

[1] International agreements are pursuant to the U.S.-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty; IBWC 1944). The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the U.S. Section of the International Boundary and Water Commission (USIBWC) in consultation with the Department of State.

strategies will primarily focus on the operation of Glen Canyon Dam and Hoover Dam but may include actions upstream and downstream of these facilities to protect critical reservoir elevations, such as use of the Colorado River Storage Project (CRSP) Upper Initial Units to release additional water if needed to protect critical infrastructure at Glen Canyon Dam, and approaches to enhance opportunities for Lower Basin water users to reduce water use (see **Map 1-1**). This Final Environmental Impact Statement (EIS) evaluates a range of operational alternatives for post-2026 reservoir management.

Developing new guidelines is difficult in this complex Basin, where critically low storage in Lake Powell and Lake Mead, significant hydrologic variability, and the anticipation of drier future conditions amplify the central tradeoff: balancing the potentially profound impacts of water-delivery reductions with the need to maintain reservoir storage. The alternatives in this Final EIS capture a broad range of management strategies to address this tradeoff, and they demonstrate that there are multiple ways to find a balance if conditions improve. If conditions do not improve, achieving a balance is more difficult, and, under critically dry futures, even large and unprecedented reductions may be needed and may not be enough to stabilize storage.

Since 2000, the Basin has been experiencing one of the worst multi-decade droughts of the last 1,200 years.[2] In the early part of this period, falling reservoir elevations, together with the lack of objective criteria for managing the reservoirs at lower levels, prompted the adoption of the 2007 Interim Guidelines. Since their adoption, average annual flows have continued to decline, and flows have been significantly below average in nearly half of the years from 2008 to 2025.[3] Despite additional responsive actions to reduce the risk to the Colorado River system's critical infrastructure[4] and water supplies, including the 2019 Colorado River DCP, storage in Lake Powell and Lake Mead continued to fall. Due to three consecutive years of below-average hydrology ending with this year's extreme dry hydrologic conditions (with the lowest snowpack since records began in 1930s), in the spring of 2026 the Department of the Interior (Department) implemented extraordinary operational measures to protect critical infrastructure at Glen Canyon Dam. At the time of publication of this Final EIS, the combined contents of Lake Powell and Lake Mead is approximately 12.5 maf, a low that has not been seen since before Glen Canyon Dam began filling in 1963.

Consistent with the Department's longstanding preference for consensus-based management of the Colorado River System, the Department and Reclamation engaged extensively with the Basin States,[5]

[2] The average streamflow from 2000 to 2025 is drier than any 26-year period in the reconstructed paleo record developed by Meko, et al, which extends back to 760 AD (Meko et al. 2007).
[3] From 2008 to 2025, Lees Ferry, AZ, natural flow was less than 75 percent of the 1991-2020 average in 7 out of 18 years.
[4] A primary concern for the Department has been to identify and implement actions to ensure Glen Canyon Dam and Hoover Dam continue to provide downstream water releases as designed and intended. Refer to **Sections 1.8.4.1 and 1.8.4.2** for more information on critical elevations.
[5] Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming

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Map 1-1
Colorado River Basin



- Major dam
- Lee Ferry Compact Point
- Lees Ferry Gaging Station
- Colorado River
- Major Colorado River tributary
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

Basin Tribes,[6] and other interested parties during development of successor operating guidelines over the course of 4 years. However, despite those efforts, the Basin States did not reach consensus on long-term guidelines prior to the completion of this EIS. Accordingly, rather than adopting long-term operating guidelines of the same duration as the 2007 Interim Guidelines, the Secretary proposes in the Preferred Alternative to adopt an operational strategy consisting of an adaptive decision framework to develop operating guidelines for Lake Powell and Lake Mead for operating years 2027 through 2036. This framework provides for more robust operational provisions than the current guidelines while preserving the flexibility to respond to changing hydrologic conditions and to incorporate future consensus recommendations, should they be reached. Should no consensus emerge, the Preferred Alternative ensures that the Secretary will have the flexibility to make necessary operational decisions.

The Secretary intends to consider, adopt, and implement the proposed federal action[7] consistent with the Law of the River,[8] including the Colorado River Compact of 1922 (Compact; 43 U.S. Code [USC] § 617l), the Consolidated Decree entered by the U.S. Supreme Court in the case of *Arizona v. California*, 547 U.S. 150 (2006; Consolidated Decree), and other provisions of applicable federal law and also recognizes that additional authorities may need to be developed. The proposed federal action would be used each year by the Department to implement the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968 (Long-Range Operating Criteria [LROC]; Colorado River Basin Project Act of 1968 [CRBPA]; Reclamation 1970) through the issuance of the Annual Operating Plan for Colorado River Reservoirs (AOP).

This Final EIS has been prepared in compliance with the National Environmental Policy Act (NEPA)[9] for the Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead (Post-2026 process). It analyzes a broad and reasonable range of alternatives for potential future guidelines and reservoir management strategies for the Colorado River. This Final EIS analyzes the tradeoffs between the frequency and magnitude of shortages, the potential effects on water storage in Lake Powell and Lake Mead, and on water supplies, power production, recreation, and other environmental resources and, in doing so, identifies the potential relevant environmental issues associated with implementing the proposed federal action.

[6] There are 30 federally recognized Native American tribes in the Basin: Ak-Chin Indian Community, Chemehuevi Indian Tribe, Cocopah Indian Tribe, Colorado River Indian Tribes, Fort McDowell Yavapai Nation, Fort Mojave Indian Tribe, Fort Yuma-Quechan Tribe, Gila River Indian Community, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Jicarilla Apache Nation, Kaibab Band of Paiute Indians, Las Vegas Paiute Tribe, Moapa Band of Paiute Indians, Navajo Nation, Pascua Yaqui Tribe, Pueblo of Zuni, Salt River Pima-Maricopa Indian Community, San Carlos Apache Tribe, San Juan Southern Paiute, Shivwits Band of Paiutes, Southern Ute Indian Tribe, Tohono O'odham Nation, Tonto Apache Tribe, Ute Indian Tribe of the Uintah and Ouray Reservation, Ute Mountain Ute Tribe, White Mountain Apache Tribe, Yavapai-Apache Nation, and Yavapai-Prescott Indian Tribe.

[7] The phrase "proposed federal action" is used herein to refer to the action that the Secretary may take to meet the purpose and need. A range of alternatives are considered in this document; a Preferred Alternative has been included in this Final EIS based on public review of the Draft EIS.

[8] The treaties, compacts, decrees, statutes, regulations, and other legal documents and agreements applicable to the allocation, appropriation, development, exportation, and management of the waters of the Basin are often referred to as the "Law of the River." There is no single, universally agreed-upon definition of the "Law of the River," but it is useful as a shorthand reference to describe this longstanding and complex body of legal agreements governing the Colorado River.

[9] 42 USC § 4321 *et seq.*

1.2 Proposed Federal Action

Reclamation, acting on behalf of the Secretary, proposes to adopt guidelines and coordinated reservoir management strategies to address operations of Lake Powell and Lake Mead through their full operating ranges. This action would improve predictability to all water users and managers in the Basin by developing and adopting objective guidelines for the operation of Glen Canyon Dam and Hoover Dam to take effect when the current operating guidelines expire in 2026. This action is designed to provide for the sustainable management of the Colorado River system and its resources under a wide range of potential future system conditions.

The proposed federal action considers the following operational elements that are collectively designed to address the purpose and need for the proposed federal action:

1) Identification of circumstances under which the Secretary would allocate, reduce, or increase the annual amount of water available for consumptive use from Lake Mead to the Lower Division States (Arizona, California, and Nevada) at, below, or above 7.5 million acre-feet (maf), pursuant to the Supreme Court Decree in *Arizona* v. *California*, 376 U.S. 340 (1964) (Final Decree entered in 2006).
2) Coordinated operations of Lake Powell and Lake Mead, particularly under low reservoir conditions.
3) Storage and delivery of conserved water in Lake Powell and/or Lake Mead to increase the flexibility to meet water use needs from both reservoirs, including the storage and delivery of non-system water; exchanges; and water conserved through extraordinary measures by or for tribal, agricultural, or municipal entities.

The proposed federal action allows for development of robust operating guidelines for Lake Powell and Lake Mead without precluding upstream or downstream actions needed to protect critical reservoir elevations at Lake Powell and Lake Mead, such as the following:

- Approaches that consider total system storage in all major Colorado River reservoirs and/or actual inflows to determine coordinated operations of Lake Powell and Lake Mead.
- Approaches that include opportunities for conservation, augmentation, demand management, or other water management strategies (such as exchanges or transfers).
- Modified operations at upstream CRSP Upper Initial Units to release additional water if needed to protect critical infrastructure at Glen Canyon Dam.

The Secretary intends that the guidelines be interim in nature and extend for the same duration as the 2007 Interim Guidelines (approximately 20 years). Adoption of new guidelines for an interim (or limited) period provides the opportunity to gain additional experience for operating the reservoirs, thereby informing future operational and water management decisions.

Recognizing additional authorities may be developed, the Department intends to adopt and implement the guidelines in a manner consistent with the Law of the River. The Department also intends that the guidelines be used to implement the LROC and applicable federal law through the issuance of the AOP.

1.3 Purpose of and Need for Action

The proposed federal action is needed for the following reasons:

- *The Secretary is legally required to coordinate operations of Colorado River reservoirs:* The CRBPA directs the Secretary to adopt criteria for the coordinated long-range operation of Colorado River reservoirs. In compliance with this obligation, the LROC were developed and adopted by the Secretary in 1970. The LROC provide general narrative guidance regarding Lake Powell and Lake Mead operations but does not contain specific, objective criteria to guide annual operations. To address this inadequacy, the 2007 Interim Guidelines were developed to provide objective criteria used by the Department to implement the LROC. The 2007 Interim Guidelines have provided the predictability needed by the entities that receive Colorado River water to better plan for and manage available water supplies from the Colorado River and other sources.
- The *2007 Interim Guidelines are expiring:* Current operational guidelines expire during the 2026 operating year. The Department has determined that specific, objective operational guidelines are important to provide improved predictability and should be established for another interim period beyond 2026. Most of the federal and non-federal agreements associated with implementing provisions of the 2007 Interim Guidelines also expire after the 2026 operating year.
- *The 2007 Interim Guidelines have not sufficiently reduced risk:* Based on operational experience since 2007, the current guidelines are not robust enough to manage the system in a way that is sufficiently protective of the resources dependent on the Colorado River. Despite near-continuous drought-response actions in recent years, low reservoir conditions have persisted, and new infrastructure risks at Glen Canyon Dam have arisen. More robust and adaptive guidelines are needed for the efficient and sustainable management of the major mainstream Colorado River reservoirs and system resources.
- *Imbalance between water supply and demand will be exacerbated by increasingly likely low-runoff conditions:* The Basin is experiencing increased aridity due to climate variability, and long-term drought and low-runoff conditions are expected in the future. These conditions will exacerbate the now widely recognized imbalance between water supply and demand in the Basin. Robust and flexible guidelines are needed to manage the Colorado River system and its resources under a broad range of potential future hydrologic conditions.
- *Expanded and innovative use of conservation is needed:* Recognizing the anticipated future low-runoff conditions in the Basin, the Department has also determined a need for guidelines that provide Colorado River water users, including Basin Tribes, expanded opportunities to conserve, store, exchange, and take subsequent delivery of water in and from Lake Powell and/or Lake Mead. The guidelines should also support and integrate future efficiency improvements and opportunities for augmentation.
- *Addressing tribal concerns regarding Basin management is needed:* Basin Tribes have expressed concern that the current approach to Colorado River water management is insufficient to address the range of interests, needs, and fundamental rights of the Basin Tribes. The Department has determined a need for guidelines that provide flexibility and predictability for Basin Tribes to

remain able to benefit from their water rights and have opportunities to participate in voluntary conservation programs.

The purpose of the proposed federal action is to:

- Update and expand management guidelines for Colorado River reservoirs, particularly for the coordinated operation of Lake Powell and Lake Mead
- Provide Colorado River water users a greater degree of predictability with respect to annual water availability in future years under anticipated increasing variability, low runoff, and low reservoir conditions
- Provide additional mechanisms for the conservation, exchange, storage, and delivery of water supplies in Colorado River reservoirs to increase the flexibility to meet water use needs
- Provide new or enhanced opportunities for Basin Tribes to benefit from their water rights
- Provide flexibility to build resilience and accommodate future needs and growth that are supported by Colorado River water supplies including the integration of unquantified tribal water rights once they are resolved

1.4 Lead and Cooperating Agencies

The Secretary is responsible for operating Glen Canyon Dam and Hoover Dam, as well as managing the mainstream waters of the lower Colorado River in accordance with federal law. These responsibilities are carried out consistent with the Law of the River. Reclamation, as the agency that is designated to act on the Secretary's behalf with respect to these matters, is the lead federal agency for the purposes of NEPA compliance and for the development and implementation of the proposed interim guidelines.

The following federal agencies are cooperating in the environmental analysis and preparation of this Final EIS:

- Bureau of Indian Affairs (BIA)
- National Park Service (NPS)
- U.S. Fish and Wildlife Service (FWS)
- U.S. Section of the International Boundary and Water Commission (USIBWC)
- Western Area Power Administration (WAPA)

1.5 Scope of the EIS

The scope of this Final EIS was informed by applicable federal law, Reclamation's operating experience under the 2007 Interim Guidelines, documentation of that experience,[10] and efforts conducted by Reclamation to gather public input on the scope of post-2026 guidelines. Before

[10] In 2020, Reclamation completed a retrospective evaluation (Reclamation 2020) to document the effectiveness of the 2007 Interim Guidelines with respect to the purpose stated in the 2007 ROD.

formally initiating the NEPA process, in June 2022, Reclamation conducted a public "pre-scoping" effort requesting input on suggested mechanisms to ensure a wide range of stakeholder participation in the process and potential substantive elements to be considered for post-2026 operations.[11] Using the input received, on June 16, 2023, Reclamation published a Notice of Intent (NOI) to prepare an environmental impact statement (EIS) in the *Federal Register* (88 *Federal Register* 39455), formally initiating the public scoping process. A Notice of Availability (NOA) for the Scoping Report (Reclamation 2023b) was published in October 2023 in the *Federal Register* (88 *Federal Register* 72535), summarizing all public comments received during the scoping period (June 16, 2023, to August 15, 2023). Over the 60-day scoping period, Reclamation engaged with stakeholders through public webinars, tribal consultations, and technical education sessions. During the scoping public comment period, Reclamation received a total of 24,290 comment submissions from a wide range of interested parties, including federal, state, and local entities; tribes; nongovernmental organizations; other stakeholder groups; and individuals. Reclamation considered the comments in developing the proposed federal action, purpose and need, and scope of the environmental analysis (see **Section 1.2**). A number of related efforts and parallel processes outside the scope of this federal action will continue independently of this Final EIS but may inform the development and implementation of new guidelines. Specifically, the Department acknowledges the importance of ongoing tribal water rights settlements and associated negotiations in the Basin. The alternatives in this Final EIS do not weigh in on or assume specific settlement terms, and the new guidelines are intended to be flexible enough to integrate tribal water rights once resolved.

The alternatives in this Final EIS are designed to cover a wide range of potential outcomes with respect to post-2026 operations; accordingly, they incorporate components that are within existing authorities along with components that would require new authorities and/or new agreements among Basin water users to fully implement. Reclamation has determined that, based on public input received during the scoping and alternative development phases of the NEPA process, analysis of these operations presents a reasonable and broad range of Colorado River operations that capture an appropriate range of potential environmental impacts. Recognizing that additional authorities and agreements may be developed, the Secretary intends to adopt and implement new guidelines in a manner consistent with the Law of the River.

1.5.1 Geographic Scope of the Proposed Federal Action and Affected Regions and Interests

Consistent with the geographic scope analyzed in the 2007 Interim Guidelines Final EIS, the geographic scope that would be affected by the proposed federal action begins at full pool of Lake Powell and extends downstream along the mainstream Colorado River floodplain to the Southerly International Boundary (SIB) with Mexico. While portions of northwestern Mexico are part of the Basin, these areas are not within the geographic scope of analysis for this EIS. This EIS does not address water deliveries to Mexico; however, in order to assess the potential effects of the proposed federal action, certain modeling assumptions regarding water deliveries to Mexico are used in this Final EIS.

[11] The pre-scoping period began with a Federal Register notice on June 24, 2022 (87 *Federal Register* 37884). The Department received substantial feedback from Basin States, Basin Tribes, water users, non-governmental organizations, and the public, which Reclamation summarized in a Pre-Scoping Summary Report (Reclamation 2023a).

This proposed federal action would also potentially affect interests of water users in the Lower Division States in service areas that extend beyond the Colorado River floodplain. Additionally, numerous tribes hold Colorado River water entitlements and could be affected by water supply availability. General operations and facilities outside the mainstream Colorado River may fall within separate Records of Decision (RODs) and authorities that are outside the scope of the proposed interim guidelines.

Although the proposed federal action is focused on Lake Powell and Lake Mead operations, management strategies that include activities upstream of Lake Powell are being analyzed in this Final EIS. These activities include Upper Basin conservation and, if warranted to protect critical reservoir elevations, coordinated operations of the CRSP Upper Initial Units (see **Map 1-1**) to release additional water within their respective Records of Decision (RODs) to increase the elevation at Lake Powell. Operations at the CRSP Upper Initial Units specifically contemplated in this Final EIS are intended to remain within the scope of the existing RODs (Reclamation 2006a, 2006b, 2012).[12] Since those RODs are covered by their own NEPA, this Final EIS does not need to expand the geographic scope of analysis upstream of Lake Powell. With respect to Upper Basin conservation, the nexus to the proposed federal action is the storage and delivery of that conserved water in Lake Powell. The effects of this storage in and delivery from Lake Powell are within the scope of the EIS (see **Section 3.3**, Hydrologic Resources, and **TA 3**, Hydrologic Resources), while specific activities that may be undertaken in the Upper Basin to generate the conserved water are not within the scope of this EIS. Any such activities are unknown at this time and will not necessarily require federal decision making. Any federal decisions associated with these conservation activities will be assessed outside of this EIS.

1.6 Application of NEPA Rules and Policy

As of April 11, 2025, the Council on Environmental Quality (CEQ) repealed its NEPA implementing regulations through a notice published in the *Federal Register* (90 FR 10610, Feb. 25, 2025), in accordance with Executive Order 14154, Unleashing American Energy (90 FR 8353; January 29, 2025), and directed agencies to revise their NEPA implementing procedures. On July 3, 2025, the Department issued an interim final rule partially rescinding its prior NEPA implementing regulations[13] and making necessary targeted updates to its remaining regulations (2025 Interim Final Rule). The Draft EIS was prepared under the 2025 Interim Final Rule. On February 24, 2026, the Department published the final rule along with 516 Department Manual 1 - U.S. Department of the Interior Handbook of National Environmental Policy Act Implementing Procedures (DOI NEPA Handbook). The Final EIS complies with Executive Orders and Department regulations and guidance for NEPA compliance.

[12] While the Secretary will consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the CRSP Upper Initial Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes as stated in the 1956 Colorado River Storage Project Act.

[13] NEPA Implementing Regulations, Interim Final Rule, Request for Comment, 43 Code of Federal Regulations (CFR) Part 46; the Department has retained and updated specific regulatory provisions regarding emergency response procedures, categorical exclusions and document preparation by applicants and contractors.

The 2025 Interim Final Rule and current implementing procedures allow for discretionary opportunities for public participation. Reclamation is using these discretionary opportunities, such as issuing the Draft EIS with a public comment period, to enhance public participation on the important topic of Colorado River operations.

This NEPA process applies to Reclamation's operation of Colorado River facilities, and those operations are inherently ongoing and cannot be suspended, including pending the development of new operating guidelines.[14] Reclamation's operations involve continuous adjustment to variable hydrologic conditions to maintain infrastructure integrity, deliver, and release water to Basin users consistent with the Law of the River. Even when operations may elicit objections, particularly under challenging hydrologic regimes, Reclamation cannot stop operating facilities until such time in the future as objections are resolved. Reclamation will continue to operate within the framework of applicable federal law, established authorities, and operational judgment aligned with any updated guidelines as necessary to respond to current and projected system conditions (see **Section 1.8.2.1** for further description).

1.7 Summary of Contents of this Final EIS

Following is a brief description of the topics presented in the four volumes that comprise this Final EIS.

Volume I of this Final EIS (this volume) describes the proposed federal action, the alternatives considered, and the analysis of the potential effects of these alternatives on Colorado River operations and associated resources. The contents of the chapters in this volume are as follows:

- **Chapter 1, Purpose and Need,** includes the following: identification of the purpose of and need for Lower Basin shortage guidelines and coordinated reservoir management strategies of Lake Powell and Lake Mead being considered in the proposed federal action; background information concerning the apportionment of Colorado River waters and the physical facilities associated with the Basin; and discussion of the institutional framework within which the Basin is managed. Chapter 1 also discusses previous and ongoing actions that have a relationship to the proposed federal action.
- **Chapter 2, Description of Alternatives,** describes the process of formulating alternatives, describes the Preferred Alternative, and presents a range of reservoir operation strategies and guidelines considered under each alternative. A summary of the performance tradeoffs between alternatives is provided at the end of Chapter 2.
- **Chapter 3, Affected Environment and Environmental Consequences,** describes the affected environment for the proposed federal action and evaluates potential impacts that could result from implementation of the alternatives. The discussion also addresses environmental consequences, i.e., potential effects of the action alternatives that could occur as compared to the No Action Alternative.

[14] See, e.g., Boulder Canyon Project Act of 1928 (BCPA), 45. Stat. 1057 (Dec. 21, 1928), sections 5 and 6; Consolidated Decree, Sections II-III.

- **Chapter 4, Consultation and Coordination,** describes the public involvement process, including public notices, scoping meetings, and hearings. This chapter also describes the coordination with federal and state agencies, Basin Tribes, and Mexico (through the USIBWC) during the preparation of this document and any permitting or approvals that may be necessary for implementation of the proposed federal action.

In addition to the above, Volume I includes a list of acronyms used throughout this document.

Volumes II and III contain appendices that are comprised of documents and other supporting material that provide detailed historical background and/or technical information concerning the proposed federal action. Volume IV contains a list of persons contributing to the preparation of the Final EIS, a list of references cited in this Final EIS, glossary of commonly used terms, and an index.

1.8 Water Supply Management and Allocation

1.8.1 Colorado River System Water Supply

The Basin includes broad areas of the southwestern U.S. and northwestern Mexico, as shown on **Map 1-1**, and occupies an area of approximately 250,000 square miles. The Colorado River is approximately 1,400 miles in length and originates along the Continental Divide in Rocky Mountain National Park in Colorado. Elevations in the Basin range from sea level to over 14,000 feet above mean sea level[15] in the mountainous headwaters.

Climate varies significantly throughout the Basin. Most of the Basin is arid and semi-arid, defined as receiving less than 10 and less than 20 inches of precipitation per year, respectively. In contrast, many of the mountainous areas that rim the northern portion, making up about 15 percent of the Basin, average over 40 inches of precipitation per year.

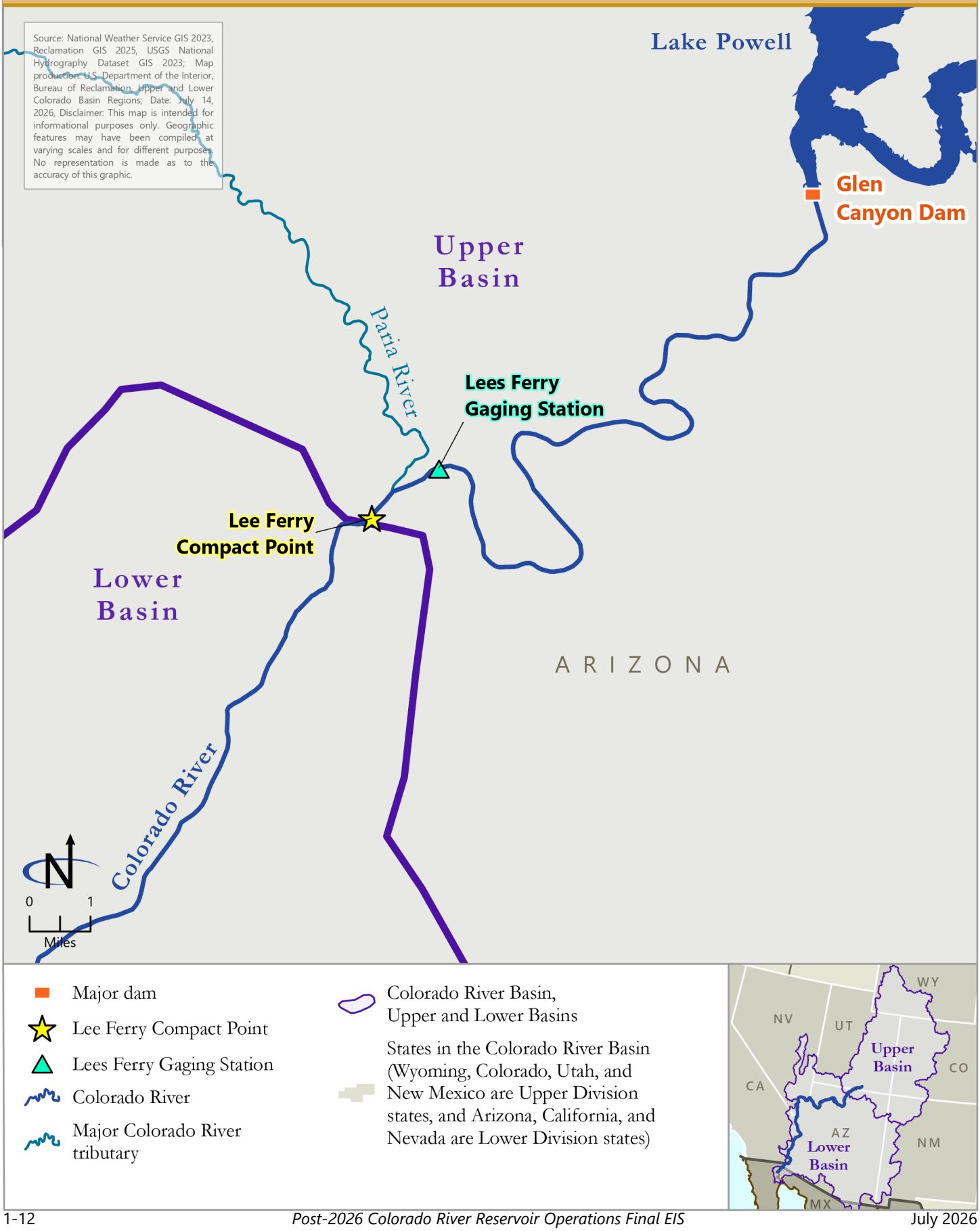
Most of the total annual flow in the Basin is a result of natural runoff from mountain snowmelt. Because of this, flow is highest in the late spring and early summer, diminishing rapidly by mid-summer. While flows in late summer through autumn sometimes increase following rain events, flow in the late summer through winter is generally low. Major tributaries to the Colorado River include the Green River, San Juan River, Yampa River, Gunnison River, and Gila River.

The annual flow of the Colorado River and its tributaries varies considerably from year to year. The natural flow at the Lees Ferry Gaging Station in Arizona (**Map 1-2**), located 15.9 river miles (RMs) downstream of Glen Canyon Dam, has varied annually from 5.0 maf to 23.0 maf. Natural flow represents an estimate of flows that would exist without human intervention (that is, without consumptive use or reservoir storage). Natural flow at Lees Ferry Gaging Station (Lees Ferry natural flow) represents the supply generated in the Upper Basin, which typically makes up approximately 92 percent of the total natural flow in the Basin as measured at Imperial Dam.

[15] Reservoir elevations are described in height above mean sea level.

— BUREAU OF —
RECLAMATION

Map 1-2
Lees Ferry Gaging Station and Lee Ferry Compact Point



The average annual Lees Ferry natural flow from 1906 to 2025 is approximately 14.6[16] maf; for the 21st Century, the average flow from 2000 to 2025 is 12.3 maf. In the Lower Basin, the average annual natural flow below Lees Ferry (including inflow from the Little Colorado River, Virgin River, and Bill Williams River) from 1906 to 2025 is approximately 0.630 maf,[17] and the average flow from 2000 to 2025 is approximately 0.479 maf.[18] For more context on the current drought in the Basin, see **Sections 1.1**, Introduction, and **3.3.1**, Hydrologic Resources.

1.8.2 Apportionment of Water Supply

This section summarizes the Law of the River, Colorado River apportionments of the Colorado River Basin States (Basin States), and the allotment to Mexico pursuant to the 1944 Water Treaty (IBWC 1944).

1.8.2.1. The Law of the River

The Secretary is vested with the responsibility to manage facilities throughout the Basin and the mainstream waters of the Lower Basin pursuant to applicable federal law. These responsibilities are carried out consistent with a body of documents referred to as the Law of the River. The Law of the River comprises numerous operating criteria, regulations, and administrative decisions included in federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary.

Particularly notable among these documents are:

1. The Colorado River Compact of 1922, which apportioned beneficial consumptive use of water between the Upper Basin and Lower Basin
2. The Boulder Canyon Project Act of 1928 (BCPA), which authorized construction of Hoover Dam and the All-American Canal (AAC), required that water users in the Lower Basin have a contract with the Secretary in order to receive water from Lake Mead, and established the responsibilities of the Secretary to direct, manage, and coordinate the operation of Colorado River dams and related works in the Lower Basin
3. The California Seven Party Agreement of 1931, which, through regulations adopted by the Secretary, established the relative priorities of rights among major users of Colorado River water in California
4. The 1944 Water Treaty (and subsequent minutes of the IBWC) related to the quantity and quality of Colorado River water delivered to Mexico
5. The Upper Colorado River Basin Compact of 1948, which apportioned the Upper Basin water supply among the Upper Division States

[16] Calendar year (cy) values. 1906-2020 natural flow data can be found here: https://www.usbr.gov/lc/region/g4000/NaturalFlow/current.html. Preliminary 2021-2025 natural flow provided by Bureau of Reclamation staff and available upon request.
[17] In 2022, Reclamation revised how natural flow is calculated in the Lower Basin; the previous method added back in estimated losses due to phreatophytes, and the current method does not.
[18] Intervening flows between Lees Ferry and Imperial Dam for 2021 through 2025 are from the Lower Basin Gain/Loss Model.

6. The Colorado River Storage Project Act of 1956 (CRSPA), which authorized a comprehensive water development plan for the Upper Basin that included the construction of Glen Canyon Dam and other facilities
7. The 1963 U.S. Supreme Court Decision in *Arizona v. California* which confirmed the BCPA's Lower Basin mainstream apportionments of 2.8 maf for use in Arizona, 4.4 maf for use in California, and 0.3 maf for use in Nevada, not including tributaries which remain for the exclusive use of each state; provided water for American Indian (Indian) reservations and other federal reservations in Arizona, California, and Nevada; and confirmed the significant role of the Secretary in managing the mainstream Colorado River within the Lower Basin
8. The 1964 U.S. Supreme Court Decree (Decree) in *Arizona v. California* which implemented the Supreme Court's 1963 decision; the Decree was supplemented over time after its adoption and the Supreme Court entered a Consolidated Decree in 2006 which incorporates all applicable provisions of the earlier-issued decrees
9. The Colorado River Basin Project Act of 1968 (CRBPA; Public Law 90-537, 82 Stat. 885), which authorized construction of a number of water development projects including the Central Arizona Project (CAP) and required the Secretary to develop the LROC and issue an AOP for mainstream reservoirs
10. The Colorado River Basin Salinity Control Act of 1974 (Public Law 93-320, 88 Stat. 266), which authorized a number of salinity control projects and provided a framework to improve and meet salinity standards for the Colorado River in the U.S. and Mexico
11. The Grand Canyon Protection Act of 1992 (Public Law 102-575, 106 Stat. 4669), which addressed the protection of resources in Grand Canyon National Park (GCNP) and in Glen Canyon National Recreation Area, consistent with applicable federal law

Other documents which are generally considered as part of the Law of the River include, but are not limited to, those listed in **Table 1-1**. Among other provisions of applicable federal law, NEPA and the Endangered Species Act of 1973 (ESA; Public Law 93-205, 87 Stat. 884), as amended, provide a statutory overlay on certain actions taken by the Secretary. For example, as noted in **Section 1.1**, preparation of this Final EIS has been undertaken pursuant to NEPA.

Table 1-1
Selected Documents Included in the Law of the River

▪ The Rivers and Harbors Act of March 3, 1899 ▪ The Reclamation Act of June 17, 1902 ▪ Reclamation of Indian Lands in Yuma, Colorado River and Pyramid Lake Indian Reservations Act of April 21, 1904 ▪ Yuma Project authorized by the Secretary on May 10, 1904, pursuant to Section 4 of the Reclamation Act of June 17, 1902 ▪ Warren Act of February 21, 1910 ▪ Protection of Property Along the Colorado River Act of June 25, 1910	▪ International Flood Control Measures, Lower Colorado River Act of August 10, 1964 ▪ Southern Nevada (Robert B. Griffith) Water Project Act of October 22, 1965 ▪ The Colorado River Basin Project Act of September 30, 1968 ▪ Criteria for the Coordinated Long-Range Operation of Colorado River Reservoirs, June 8, 1970, amended March 21, 2005 ▪ Supplemental Irrigation Facilities, Yuma Division Act of September 25, 1970

- Patents and Water-Right Certificates Acts of August 9, 1912, and August 26, 1912
- Yuma Auxiliary Project Act of January 25, 1917
- Availability of Money for Yuma Auxiliary Project Act of February 11, 1918
- Sale of Water for Miscellaneous Purposes Act of February 25, 1920
- Federal Power Act of June 10, 1920
- The Colorado River Compact of November 24, 1922
- The Colorado River Front Work and Levee System Acts of March 3, 1925, and January 21, 1927–June 28, 1946
- The Boulder Canyon Project Act of December 21, 1928
- The California Limitation Act of March 4, 1929
- The California Seven Party Agreement of August 18, 1931
- The Parker and Grand Coulee Dams Authorization of August 30, 1935
- The Parker Dam Power Project Appropriation Act of May 2, 1939
- The Reclamation Project Act of August 4, 1939
- The Boulder Canyon Project Adjustment Act of July 19, 1940
- The Flood Control Act of December 22, 1944
- Water Treaty between the United States and Mexico Relating to the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande of February 3, 1944
- Gila Project Act of July 30, 1947
- The Upper Colorado River Basin Compact of October 11, 1948
- The Consolidated Parker Dam Power Project and Davis Dam Project Act of May 28, 1954
- The Palo Verde Diversion Dam Act of August 31, 1954
- Change Boundaries, Yuma Auxiliary Project Act of February 15, 1956
- The CRSPA of April 11, 1956
- The Water Supply Act of July 3, 1958
- The Boulder City Act of September 2, 1958
- Report of the Special Master, Simon H. Rifkind, *Arizona v. California*, et al., December 5, 1960
- The Consolidated Decree entered by the United States Supreme Court in the case of *Arizona v. California*, 547 U.S. 150 (2006)
- 43 CFR 417, Lower Basin Water Conservation Measures, September 7, 1972
- Minute 218, March 22, 1965; Minute 241, July 14, 1972 (replaced Minute 218); Minute 242, August 30, 1973 (replaced Minute 241); Minute 306, December 12, 2000; Minute 317, June 27, 2010; Minute 318, December 17, 2010; Minute 319, November 20, 2012; Minute 323, September 21, 2017; and Minute 330, March 21, 2024, of the 1944 Water Treaty
- The Colorado River Basin Salinity Control Act of June 24, 1974
- The Hoover Power Plant Act of August 17, 1984
- Numerous Colorado River Water Delivery and Project Repayment Contracts with the States of Arizona and Nevada, cities, water districts, and individuals
- Hoover and Parker-Davis Power Marketing Contracts
- The Reclamation States Emergency Drought Relief Act of 1991
- The Grand Canyon Protection Act of October 30, 1992
- Operation of Glen Canyon Dam, ROD (1996)
- Interim Surplus Guidelines ROD, January 17, 2001 (66 *Federal Register* 7772)
- Interim 602(a) Storage Guideline, May 19, 2004 (69 *Federal Register* 28945)
- The Colorado River Water Delivery Agreement of October 10, 2003 (69 *Federal Register* 12202)
- Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead ROD, December 13, 2007 (73 *Federal Register* 19873)
- Hoover Power Allocation Act of December 20, 2011
- Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) ROD, December 2016
- Colorado River Drought Contingency Authorization Act (Public Law 116-14) - Colorado River Basin DCP
- Supplement to the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead ROD, May 6, 2024
- Supplement to the 2016 Glen Canyon Dam LTEMP ROD, July 3, 2024

1.8.2.2. Apportionment to the Basin States

The initial apportionment of water from the Colorado River was determined as part of the Compact, which divided the Colorado River system into two sub-basins, the Upper Basin and the Lower Basin. The Upper Basin includes those parts of the states of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters drain naturally into the Colorado River above the Lee Ferry Compact Point in Arizona. The Lower Basin includes those parts of the states of Arizona, California, Nevada, New Mexico, and Utah within and from which waters drain naturally into the Colorado River below the Lee Ferry Compact Point. The Compact also divided the seven Basin States into the Upper Division and the Lower Division States (**Map 1-1**). The Upper Division States are Colorado, New Mexico, Utah, and Wyoming. The Lower Division States are Arizona, California, and Nevada.

The Compact apportioned to the Lower Basin and the Upper Basin, in perpetuity, the exclusive beneficial consumptive use of 7.5 maf of water per year (mafy). In addition to this apportionment, Article III(b) of the Compact gives the Lower Basin the right to increase their beneficial consumptive use by 1.0 mafy. The Compact also stipulates in Article III(d) that the Upper Division States will not cause the flow of the river at the Lee Ferry Compact Point to be depleted below an aggregate of 75.0 maf for any period of ten consecutive years. Article III(c) reflects the intent that any future water deliveries to Mexico be supplied first from surplus Colorado River water and, if surplus is insufficient, that the resulting deficiency be shared equally between the Upper and Lower Basins.

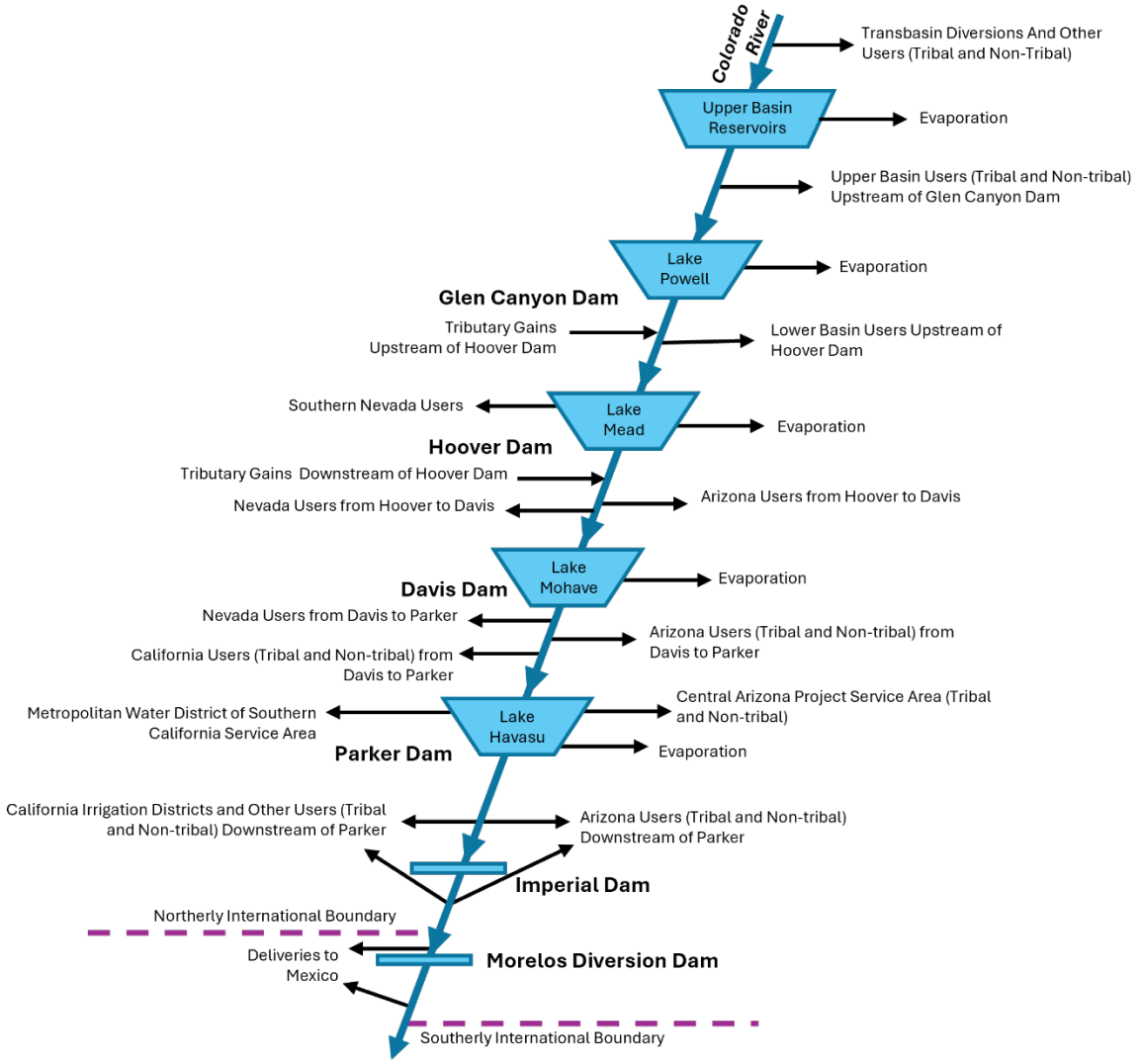
The Compact, in Article VII, states that nothing in the Compact shall be construed as affecting the obligations of the U.S. to Indian tribes. Tribal rights to mainstream Colorado River water were subsequently adjudicated in the Consolidated Decree. To the extent that Indian tribes consumptively use water from the mainstream Colorado River, such uses are included in the apportionment of the appropriate Basin State.

Upper Division State Apportionments. Upper Division State apportionments were established by the Upper Colorado River Basin Compact of 1948. These apportionments allocate the Upper Division States' consumptive use after deduction of up to 50 thousand acre-feet per year (kafy) for Arizona as follows: Colorado, 51.75 percent; New Mexico, 11.25 percent; Utah, 23.00 percent; and Wyoming, 14.00 percent. The Upper Basin State apportionments have not yet been fully developed.

Lower Division State Apportionments. Lower Division State apportionments were established by Congress in the BCPA and by the Secretary's water delivery contracts under the BCPA. These apportionments are: Arizona, 2.8 maf; California, 4.4 maf; and Nevada, 0.3 maf; totaling 7.5 maf, subject to annual increases or reductions pursuant to Secretarial determinations of a Surplus or a Shortage Condition. Under Article II(B)(2) of the Consolidated Decree, when the Secretary determines that there is a Surplus Condition, 46 percent of the available water supply in excess of 7.5 maf may be apportioned for use in Arizona; 50 percent for use in California; and 4 percent for use in Nevada.

Figure 1-1 presents a schematic of the operation of the Colorado River. The Consolidated Decree confirms the apportionments to the Lower Division States established by the BCPA and guides the Secretary's operation of facilities, including Hoover Dam, on the lower Colorado River. Under the Consolidated Decree, if water apportioned for use in a Lower Division State is not consumed by that state in any year, the Secretary may release the unused water for use in another Lower Division State. Water that is stored off-stream by a Lower Division State (for future use by that state or by another Lower Division State) is accounted as consumptive use to the state that stored the water in the year it was stored.

Figure 1-1
Colorado River Reservoirs and Diversions



All mainstream Colorado River waters apportioned to the Lower Basin, except for a few kaf apportioned for use in Arizona, have been fully allocated to specific entities for permanent irrigation or domestic[19] use entitlements. These entities include irrigation districts, water districts, municipalities, Indian tribes, public institutions, private water companies, and individuals. Federal establishments with federal reserved rights established pursuant to Article II(D) of the Consolidated Decree are not required to have a contract with the Secretary, but the water allocated to a federal establishment is included within the apportionment of the Lower Division State in which the federal establishment is located; e.g., Fort Mojave Indian Reservation in California and the Havasu National Wildlife Refuge (NWR) in Arizona.

The highest priority lower Colorado River water rights are present perfected rights (PPRs), which the Consolidated Decree defines as those perfected rights existing on June 25, 1929, the effective date of the BCPA.[20] The Consolidated Decree quantified PPRs including federal Indian reserved rights on five Indian reservations along the lower Colorado River. PPRs are important because in any year in which less than 7.5 maf of Colorado River water is available for consumptive use in the Lower Division States, PPRs will be satisfied first, in the order of their priority without regard to state lines.

Waters available to a Lower Division State within its apportionment, but having a priority date later than June 25, 1929, have been allocated by the Secretary through execution of water delivery contracts to water users within that state as required by Section 5 of the BCPA. The Lower Division States have intrastate priority systems in accordance with those contracts.

1.8.2.3. Allotment to Mexico (Pursuant to the 1944 Water Treaty)

Allocation of Colorado River water to Mexico is governed by the 1944 Water Treaty. Article 10(a) of the 1944 Water Treaty states:

> "(a) A guaranteed annual quantity of 1,500,000 acre-feet (af; 1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty"

Further, Article 10(b) of the 1944 Water Treaty provides:

> "(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 acre-feet (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of waters of the Colorado River system, for any purpose whatsoever, in excess of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually."

[19] The term "domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power (1922 Compact, Article II(h)).
[20] Priority is a ranking with respect to diversions of water relative to other water users.

Additionally, Article 10 of the 1944 Water Treaty provides:

> "In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced."

The proposed federal action is for the purpose of adopting additional operational guidelines to improve the Department's management and operation of key Colorado River reservoirs for an interim period. However, in order to assess the potential effects of the proposed federal action in this Final EIS, certain modeling assumptions (discussed in **Chapter 2** and **Appendix S**) are used that display projected water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

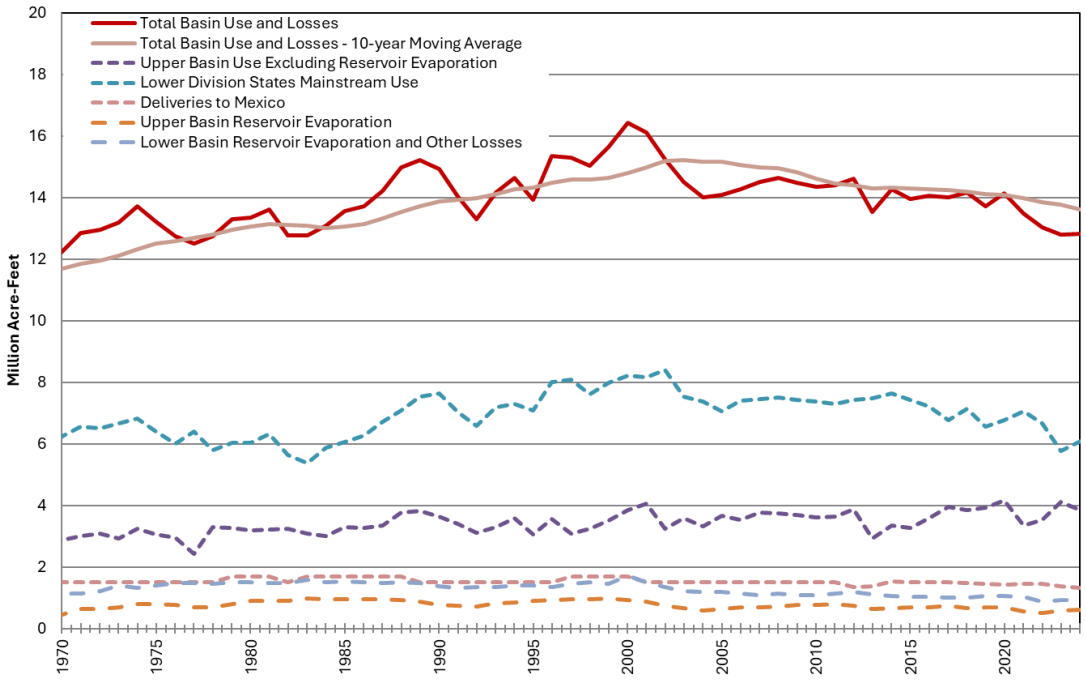
The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

1.8.3 Colorado River Basin Water Use

Total annual water "use" in the Basin is made up of diversions from the river, deliveries from reservoirs, and evaporation and other losses (e.g., seepage into the ground and usage by riparian vegetation). **Figure 1-2**, Historical Annual Colorado River Basin Use, shows Basin uses and losses from 1970 to 2024 as total Basin use and also shows use separated geographically and by category (use or evaporation and losses).

From 1970 to 2001, Upper Basin use varied between approximately 2.4 maf and approximately 4.1 maf, with a general upward trend over time. Since 2001, Upper Division States' use has varied within a similar range of volumes. Lower Division States' mainstream use increased from approximately 5.4 maf to approximately 8.4 maf from 1970 to 2002, and deliveries to Mexico were steady around 1.5 maf. Shortly after the onset of the ongoing drought in 2000, use began to decline. In the Lower Division States, the decline began after adoption of the Interim Surplus Guidelines in 2001, which brought California's water use to within its apportionment. After adoption of the 2007 Interim Guidelines, Lower Division States began significant conservation efforts, and drought-response activities since their adoption have resulted in continued reductions in use. The first year of shortages under the 2007 Interim Guidelines occurred in 2022. Evaporation and other losses declined between 2000 and 2024 because evaporation decreases as Lake Powell and Lake Mead elevations decline.

Figure 1-2
Historical Annual Colorado River Basin Use



Note: Use and losses includes consumptive use by the U.S. Colorado River Basin States and Mexico, reservoir evaporation, and other losses; use data from Upper Colorado River System Consumptive Uses and Losses Reports and Lower Colorado River Basin Water Accounting Reports.

1.8.4 System Reservoirs and Diversion Facilities

The Colorado River System contains numerous reservoirs that provide an aggregate of approximately 60.0 maf of storage (or roughly 4 years of average flow of the Colorado River). Of these reservoirs, Lake Powell and Lake Mead provide approximately 85 percent of this storage. Lake Powell, formed by Glen Canyon Dam, provides 23.3 maf of this storage.

The Lower Basin dams and reservoirs include Hoover Dam, Davis Dam, and Parker Dam (**Map 1-3**). Lake Mead, formed by Hoover Dam, can store up to 26.1 maf (27.6 maf at full pool less 1.5 maf of exclusive Flood Control space). Davis Dam was constructed by Reclamation to re-regulate Hoover Dam's releases and to aid in the annual delivery of 1.5 maf to Mexico. Davis Dam created Lake Mohave and provides 1.8 maf of storage. Parker Dam formed Lake Havasu (0.65 maf of storage) from which water is pumped by both Metropolitan Water District of Southern California (MWD) and the CAP. Parker Dam re-regulates releases from Davis Dam and from the U.S. Army Corps of Engineers' (USACE's) Alamo Dam on the Bill Williams River, and in turn releases water for downstream use in the U.S. and Mexico. Other Lower Basin mainstream reservoirs, shown on **Map 1-3**, are operated primarily for the purpose of river flow regulation to facilitate diversion of water to Arizona, California, and Mexico. Diversion facilities of the Lower Division States typically serve multiple entities.


BUREAU OF RECLAMATION
Map 1-3
Lower Basin Dams and Reservoirs
Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: July 14, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.
0
25
Miles
N
NEVADA
Muddy River
Virgin River
Lake Mead
Hoover Dam
Lake Mohave
Davis Dam
Lower Basin
CALIFORNIA
ARIZONA
Lake Havasu
Parker Dam
Bill Williams River
Headgate Rock Dam
Alamo Dam
Palo Verde Diversion Dam
Colorado River
Salton Sea
New River
Alamo River
Warren H. Brock Reservoir
Senator Wash Dam
Imperial Dam
Laguna Dam
USA
MEXICO
Morelos Diversion Dam
Gila River
All-American Canal
Gila Gravity Main Canal
Colorado River
Major Colorado River tributary
Salton Sea tributary
Canal
Dam or diversion
Waterbody
Colorado River Basin, Upper and Lower Basins
States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)
WY
NV
UT
CO
CA
AZ
NM
MX
Upper Basin
Lower Basin

There are several points of diversion in Arizona. Arizona can use up to 50 kafy of water under its Upper Basin apportionment. In the Lower Basin, the largest diversion for Arizona is the CAP pumping plant on Lake Havasu downstream of the confluence of the Bill Williams River. Irrigation water for the Fort Mojave Indian Reservation, near Needles, California, is pumped from both wells and pumps along the river channel. There are also several other municipal, industrial, and agricultural water users located along the Colorado River that pump their water from wells. Irrigation water for the Colorado River Indian Reservation near Parker, Arizona, is diverted at Headgate Rock Dam, which was constructed for that purpose. A river pumping plant in the Cibola area provides water to irrigate lands adjacent to the Colorado River. The last major diversion for Arizona occurs at Imperial Dam, where water is diverted into the Gila Gravity Main Canal for irrigation for the Gila and Wellton-Mohawk projects and into the AAC for subsequent release into the Yuma Main Canal for the Yuma Project and the City of Yuma.

California receives most of its Colorado River water at three diversion points: MWD's pumping plant on Lake Havasu; the Palo Verde Irrigation District's diversion at the Palo Verde Diversion Dam near Blythe, California; and the AAC diversion at Imperial Dam (**Map 1-3**).

In Nevada, the state's consumptive use apportionment of Colorado River water is used almost exclusively for municipal and industrial (M&I) purposes. About 90 percent of this water is diverted from Lake Mead at a point approximately 5 miles northwest of Hoover Dam at Saddle Island by the Southern Nevada Water Authority (SNWA) facilities. The remainder of Nevada's diversion occurs downstream of Davis Dam in the Laughlin, Nevada area and on the Fort Mojave Indian Reservation.

1.8.4.1. Critical Infrastructure Considerations at Glen Canyon Dam

Glen Canyon Dam is a National Critical Infrastructure site. Full pool is at elevation 3,700 feet, and dead pool is at elevation 3,370 feet (see **Figure 1-3**). There are three mechanisms for releasing water through the dam (see **Figure 1-4**): the spillways, the penstocks, and the river outlet works. The penstocks route water through turbines in the hydropower generating plant, and the river outlet works route water through four jet tubes. Water can be released through the spillways from full pool down to elevation 3,648 feet. Water can be released through the penstocks down to elevation 3,490 feet, which is minimum power pool. Water can be released from the river outlet works down to elevation 3,370 feet, which is the dead pool elevation.[21]

On March 26, 2024, Reclamation released a technical decision memorandum to guide operations at Glen Canyon Dam during low reservoir elevations (Reclamation 2024a). Glen Canyon Dam was not intended to operate for an extended period of time below minimum power pool (elevation 3,490 feet). Below this elevation, water cannot be released through the penstocks and must instead be released through the river outlet works. Infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam include potential cavitation damage to the outlet works pipes at low reservoir elevations, tailrace scour and sediment deposition at the downstream base of the dam, and the potential for additional unknown issues from operating the outlet works for extended periods. Any one of these

[21] Emergency and other operations are further described in **Section 2.3**, footnote 7.

Figure 1-3
Glen Canyon Dam Key Elevations

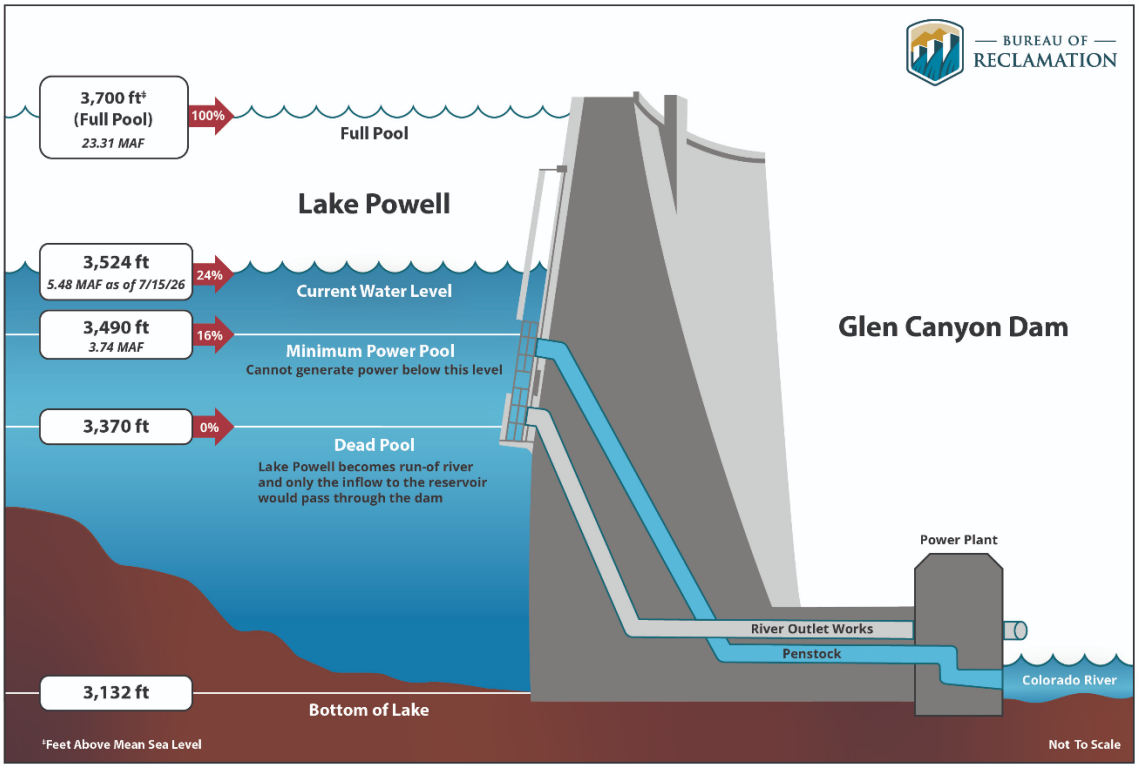
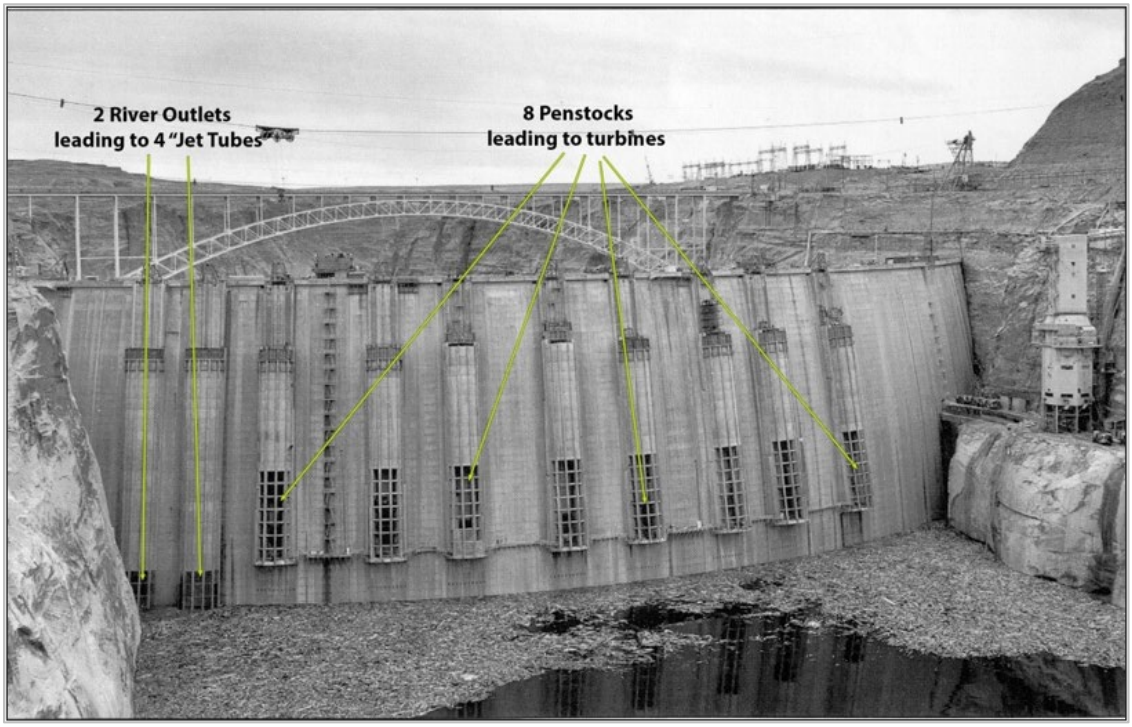


Figure 1-4
Glen Canyon Dam in 1963 (Before Filling)



factors could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs. The foregoing concerns informed the design of the Preferred Alternative to reduce the likelihood of having to rely on the river outlet works as the sole means of sustained water releases from Glen Canyon Dam. Alterations to the dam to reduce some of these risks and uncertainties are being contemplated but are outside the scope of this EIS and speculative; therefore, they are not analyzed in this document.

1.8.4.2. Critical Infrastructure Concerns at Hoover Dam

Hoover Dam is a National Critical Infrastructure site. Maximum pool elevation is elevation 1,229 feet, and dead pool is elevation 895 feet (see **Figure 1-5**). There are two mechanisms for releasing water through the dam (see **Figure 1-6**). There are four intake towers, two on each side of the dam, that draw water to four penstocks. These penstocks route water through the turbines in the hydropower generating plant and can also route water to two sets of river outlet works. If the reservoir is above elevation 1,205 feet, water can also be moved through two spillways, one on each side of the dam. However, normal operating practice is to not pass water through the spillways until the reservoir is at the top of the raised spillway (at elevation 1,221 feet) for flood control purposes. Minimum power pool elevation is estimated to be 950 feet and the bottom of the intake towers for the penstocks is elevation 895 feet (dead pool). Below elevation 950 feet, water can no longer be passed through the turbines and can only be passed through the river outlet works, resulting in release constraints at low elevations. The Hoover Dam hydropower plant has 17 total hydropower turbines including five wide-head turbines. All 17 turbines can generate power down to elevation 1,035 feet, but only the five wide-head turbines can continue to produce power below 1,035 feet to 950 feet. It is estimated that there would be a 70-percent loss of total generation capacity below elevation 1,035 feet.

Figure 1-5
Hoover Dam Key Elevations

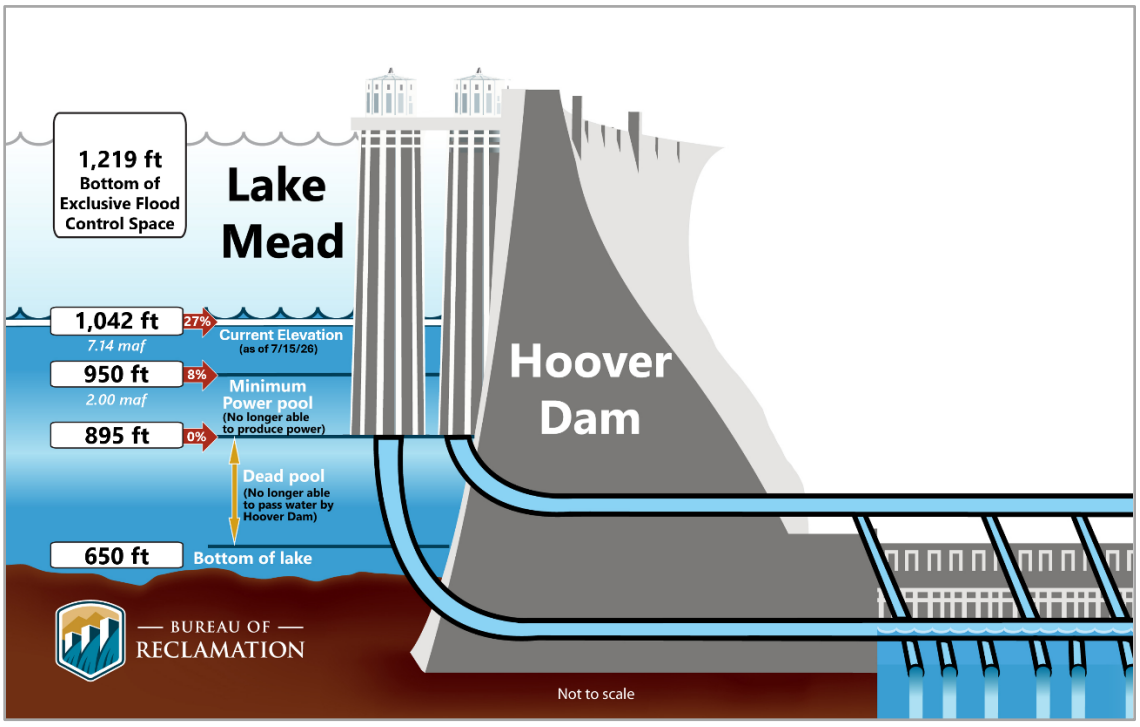
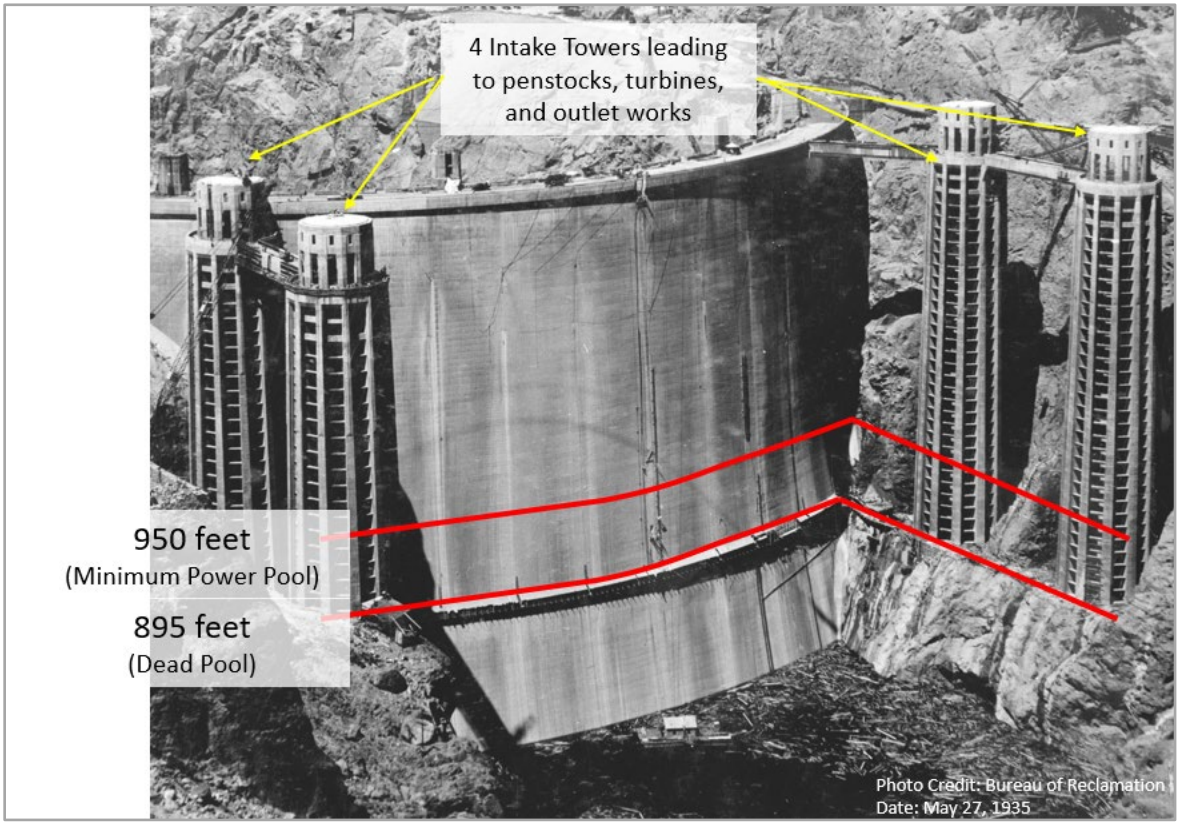


Figure 1-6
Hoover Dam in 1935 (before filling)



1.8.5 Flood Control Operation

Under the BCPA, flood control is specified as the project purpose having first priority for the operation of Hoover Dam. Subsequently, Section 7 of the Flood Control Act of 1944 established that the Secretary of War (now the USACE) will prescribe regulations for Flood Control for projects authorized wholly or partially for such purposes.

The Los Angeles District of the USACE published the current Flood Control regulations in its Water Control Manual for Flood Control, Hoover Dam and Lake Mead, Colorado River, Nevada and Arizona (Water Control Manual) dated December 1982. The Field Working Agreement between the USACE and Reclamation for the Flood Control operation of Hoover Dam and Lake Mead, as prescribed by the Water Control Manual, was signed on February 8, 1984. The Flood Control plan is the result of a coordinated effort between the USACE and Reclamation; however, the USACE is responsible for providing the Flood Control regulations and has authority for final approval. The Secretary is responsible for operating Hoover Dam in accordance with these regulations. Deviation from the Flood Control operating criteria must be authorized by the USACE.

1.8.6 Hydropower Generation

Reclamation is authorized by legislation to produce electric power at Glen Canyon Dam, Hoover Dam, Davis Dam, Parker Dam, and other smaller facilities. While Reclamation is the federal agency authorized to produce power at the major Colorado River system dams, WAPA is the federal agency

authorized to market and deliver this power. WAPA enters into electric service contracts on behalf of the U.S. with public and private utility systems for distribution of hydroelectric power produced at Reclamation facilities in excess of project demand. Glen Canyon, Hoover, Davis, and Parker Dams have a maximum combined capacity of approximately 3,769 megawatts (MW), which WAPA markets to more than 182 customers across Arizona, California, Colorado, Nebraska, Nevada, New Mexico, Utah, and Wyoming.

1.8.7 Long Range Operating Criteria and AOP

The CRBPA required the Secretary to consult with the Governors of the Basin States to adopt operating criteria for the Colorado River by July 1, 1970. The LROC, adopted in June 1970 by the Secretary (*35 Federal Register* 8951), address operation of the Colorado River reservoirs in compliance with requirements set forth in the Compact, the CRSPA, the BCPA, the 1944 Water Treaty, and other applicable federal laws. The CRBPA also provided that beginning on January 1, 1972, and annually thereafter, the Secretary "shall transmit to the Congress and to the Governors of the Colorado River Basin States a report describing the actual operation under the [LROC] for the preceding compact water year and the projected operation for the current year." This annual transmittal is known as the AOP.

Section 602 of the CRBPA, as amended, provides that the LROC can only be modified after correspondence with the governors of the Basin States and appropriate consultation with such state representatives as each governor may designate.

1.8.7.1. LROC Provisions

Under the applicable provisions of the CRBPA, the Secretary makes annual determinations in the AOP regarding the availability of Colorado River water for deliveries to the Lower Division States. A requirement to equalize storage between Lake Powell and Lake Mead when there is sufficient storage in the Upper Basin is also included in the LROC, as required by the CRBPA. Equalization releases are made if: 1) the end of the water year (WY) storage projection for Lake Powell is greater than that of Lake Mead; and 2) the storage projection for the end of the WY in the Upper Basin reservoirs is greater than the quantity of storage required by Section 602(a) of the CRBPA (602(a) storage) for that same date.

The 602(a) storage quantity is the storage in the Upper Basin necessary to assure obligations to the Lower Basin without impairing consumptive use requirements in the Upper Basin. The LROC offers factors to be considered to determine 602(a) storage but does not present a set formula. The factors to be considered include the historical stream flows, the most critical period of record, probability of available waters, and estimated future depletions in the Upper Basin. In the event that the elevation of Lake Powell is below the 602(a) storage guideline, and equalization is not required, the LROC provide that "the objective shall be to maintain a minimum release of water from Lake Powell of 8.23 maf for that year." Reclamation recognizes that entities in the Basin have different legal positions regarding how this LROC statement incorporates other Law of the River elements to determine annual releases. The Secretary has expressly recognized that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted (Norton 2005). The LROC expressly note that releases from Lake Powell pursuant to the LROC or any adopted

guidelines "shall not prejudice the position of either the Upper or Lower Basin interests with respect to the required deliveries at Lee Ferry pursuant to the Colorado River Compact."

In the AOP, the Secretary is required to report on the determination of when Normal, Surplus, or Shortage Conditions occur in the lower Colorado River, based on various factors including storage and hydrologic conditions in the Basin.

1.8.7.2. LROC Implementing Criteria and Guidelines

Beginning in 1999, the Department recognized the need for more specific and objective provisions to implement the LROC and solicited input from the Governors and the general public in the *Federal Register* (64 *Federal Register* 27009). Rather than modifying the content of the LROC, the Department chose to develop more specific, objective criteria to implement the LROC. *Federal Register* (64 *Federal Register* 68373 and 65 *Federal Register* 42028). Interim criteria and guidelines to implement the LROC were developed in 2001 and 2007, addressing both Glen Canyon and Hoover Dam operations (66 *Federal Register* 7772 and 73 *Federal Register* 19873).[22] This NEPA process will develop the next set of LROC implementing guidelines to succeed those adopted in 2007.[23]

Among other provisions described in **Section 1.8.7.1**, the LROC provide that "the objective shall be to maintain a minimum release of water from Lake Powell of 8.23 maf for that year." Despite the operational challenges due to prolonged drought, the release from Lake Powell over the term of the 2007 Interim Guidelines has met or exceeded the minimum objective release of 8.23 maf in 13 out of 19 years, and has averaged 8.5 maf over the 2008-2026 period. Going forward, the Department recognizes the continued importance of operating to achieve a minimum objective release of 8.23 maf, but meeting this objective release has been and will be increasingly difficult in a constrained system of low reservoir elevations, declining river flows, and the need to protect the operational reliability of Glen Canyon Dam.

1.8.7.3. Normal Water Supply Condition

A Normal Condition exists when the Secretary determines that sufficient mainstream water is available to satisfy 7.5 maf of annual consumptive use in the Lower Division States. Pursuant to the Consolidated Decree, if a state will not use all of its apportioned water for the year, the Secretary may allow other states of the Lower Division to use the unused apportionment, provided that the use is authorized by a water delivery contract with the Secretary.

[22] Additionally, in 2004, Reclamation adopted an interim 602(a) storage guideline, in effect through 2026, which established that Lake Powell's elevation must be above 3,630 feet (which corresponds to storage of approximately 14.85 maf) for equalization releases to occur (Reclamation 2004). The 2007 Interim Guidelines included an Equalization Tier defined by an elevation schedule that would be used in determining when equalization releases would be made from Lake Powell (generally called the "Equalization Line").

[23] Prior to 2007, the Department conducted 5-year periodic reviews of the LROC. Implementation of the 2007 Guidelines included objective consultation provisions and a review conducted in 2020 (Reclamation 2020) that served the same function as the previous period reviews. The adaptive nature of the Preferred Alternative will require at a minimum biennial reconsideration of operations and is anticipated to serve the same purpose as the formal 5-year periodic reviews during the term of the action proposed in this NEPA process.

1.8.7.4. Surplus Water Supply Condition

A Surplus Condition exists when the Secretary determines that sufficient mainstream water is available for release to satisfy consumptive use in the Lower Division States in excess of 7.5 maf annually. This excess consumptive use is surplus and is distributed for use in Arizona, California, and Nevada pursuant to the terms and conditions provided in the Interim Surplus Guidelines (ISG), adopted in 2001, as modified by the 2007 Interim Guidelines. Other than 70(R) and Flood Control surplus determinations, surplus guidelines expire with the expiration of the 2007 Interim Guidelines.

In general terms, under the 2007 Interim Guidelines, the availability of surplus water is determined by the elevation of Lake Mead. When Lake Mead is full and Reclamation is making Flood Control releases, surplus supplies are unlimited. As Lake Mead's elevation drops, surplus water amounts are reduced and ultimately eliminated.

Pursuant to the Consolidated Decree, if a state does not use all of its apportioned water for the year, the Secretary may allow other Lower Division States to use the unused apportionment, provided that the use is authorized by a water delivery contract with the Secretary.

1.8.7.5. Shortage Water Supply Condition

A Shortage Condition exists when the Secretary determines that insufficient mainstream water is available to satisfy 7.5 maf of annual consumptive use in the Lower Division States. The Secretary is authorized to determine both the timing of the initiation of a Shortage Condition and the volume of any shortage. When making a shortage determination, the Secretary must consult with various parties as set forth in the Consolidated Decree and consider all relevant factors as specified in the LROC, including 1944 Water Treaty obligations, the priorities set forth in the Consolidated Decree, and the reasonable consumptive use requirements of mainstream water users in the Lower Division States. Under the 2007 Interim Guidelines, the 2019 Lower Basin Drought Contingency Plan Agreement, and related intrastate agreements, distribution of reductions were agreed to among the Lower Division States, tribes, and water entitlement holders prior to implementation. Without these agreements, the Secretary follows the Law of the River, which includes applicable priorities, as described below, to distribute reductions.

In the Lower Basin, PPRs, generally those established before June 25, 1929, must be addressed first and in priority-date order across state lines under the *Arizona v. California* Consolidated Decree. The CRBPA also requires junior, post-1968 supplies, including much of the Central Arizona Project supply, to be limited before uses in California are reduced. Within these legal constraints, the Secretary retains discretion over how any remaining shortage volume is apportioned among Arizona, California, and Nevada (see **Appendix C** for further discussion).

In the absence of adoption of new, specific shortage criteria through this proposed action, a shortage determination would most likely be made on an annual basis through the AOP process. This is a process by which the interests of the different stakeholders are addressed through consultation. In this consultation process, water users who rely on the Colorado River in the Lower Division States would not be able to identify in advance particular reservoir conditions under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead, nor would they be able to understand the frequency or magnitude of any potential future annual reductions in their water deliveries.

1.9 Related Actions

The alternatives considered in this Final EIS address operation and storage of water in Lake Powell and Lake Mead. While there are many actions related to the operation of the Colorado River with respect to the proposed federal action analyzed in this Final EIS, Reclamation has identified seven primary documents that are related to, or would assist the reader in understanding the issues analyzed in this process:

- Off-stream Storage of Colorado River Water and Development and Release of Intentionally Created Unused Apportionment in the Lower Division States – 43 CFR pt. 414 (1999);
- Implementation Agreement, Inadvertent Overrun and Payback Policy, and Related Federal Actions - Final EIS (Reclamation 2002) and ROD - Colorado River Water Delivery Agreement (Reclamation 2003);
- Lower Colorado River Multi-Species Conservation Program (LCR MSCP) - Final Programmatic EIS/Environmental Impact Report (Reclamation 2004) and ROD - Lower Colorado River Multi-Species Conservation Plan (Reclamation 2005);
- CRSP Upper Initial Units RODs (Reclamation 2006a, 2006b, 2012);
- 2007 Interim Guidelines (Reclamation 2007a) and Near-term Colorado River Operations, Final Supplemental Environmental Impact Statement (SEIS) (Reclamation 2024b);
- LTEMP – Final EIS (Reclamation 2016) and LTEMP - Final SEIS (Reclamation 2024c) address sub-annual releases from Glen Canyon Dam; and
- 2019 Colorado River DCP (Reclamation 2019).

The actions documented in the references listed above are summarized below.

1.9.1 Off-stream Storage of Colorado River Water and Development and Release of Intentionally Created Unused Apportionment in the Lower Division States

In 1999, the Department adopted a rule to facilitate off-stream storage of Colorado River water and development and release of "Intentionally Created Unused Apportionment" for the Lower Division States. Reclamation prepared an Environmental Assessment to assess the environmental impacts of the rule, and a Finding of No Significant Impact was issued on October 1, 1999. The final rule was published in the Federal Register on November 1, 1999, and is codified at 43 CFR pt. 414.

This rule establishes a procedural framework within the Lower Basin States for an authorized entity in one state to enter into storage agreements with authorized entities in another state for the off-stream storage (and future recovery) of Colorado River water. Under the agreements, the storing state will use water it stores under an interstate agreement and, in return, at a future date, decrease its consumptive use of Colorado River water, thereby developing the ICUA that the Secretary will release for consumptive use in the consuming state. Under this rule, two Storage and Interstate Release Agreements (SIRAs) have been executed to date.[24]

[24] SIRA Contract No. 02-XX-30-W0406 was entered into on December 18, 2002, among Nevada, Arizona, and the U.S.; SIRA Contract No. 04-XX-30-W0430 was entered into on October 27, 2004, among Nevada, California, and the U.S.

1.9.2 Implementation Agreement, Inadvertent Overrun and Payback Policy and Related Federal Actions – Final EIS and ROD – Colorado River Water Delivery Agreement

California's Colorado River Water Use Plan called for conservation measures to be put in place that would reduce California's historical dependency on Colorado River water in excess of the state's 4.4 maf apportionment. The Colorado River Water Delivery Agreement, signed by the Secretary on October 10, 2003, provides for implementation of major components of California's Colorado River Water Use Plan and incorporates contractual agreements that facilitate California's sharing and distribution of Colorado River water within its 4.4 mafy entitlement.

The 2003 Colorado River Water Delivery Agreement is the Secretary's agreement to make those Colorado River water deliveries specified in the agreements with the relevant California entities for a period of up to 75 years. These agreements provide for the conservation and transfer of about 400 kaf of water annually among the Imperial Irrigation District (IID), Coachella Valley Water District (CVWD), MWD, and San Diego County Water Authority.

1.9.3 Lower Colorado River Multi-Species Conservation Program

The LCR MSCP is a 50-year cooperative effort between federal and non-federal entities, approved by the Secretary in April 2005. The LCR MSCP provides ESA compliance for specific covered federal actions and non-federal activities under ESA Sections 7 and 10. The LCR MSCP provides ESA coverage for non-federal actions that are related to the use and management of the lower Colorado River.

In addition to the covered activities of the non-federal LCR MSCP entities, specific present and potential future actions of six federal agencies on the lower Colorado River are also included in the LCR MSCP. Those federal agencies are Reclamation, BIA, NPS, Bureau of Land Management (BLM), WAPA, and FWS. These federal agencies and non-federal entities are collectively referred to as the LCR MSCP participants. The covered actions and activities for the LCR MSCP participants occur along the lower Colorado River in Imperial, Riverside, and San Bernardino counties, California; La Paz, Mohave, and Yuma counties, Arizona; and Clark County, Nevada. The duration of the Section 10 permit and the associated formal ESA Section 7 consultation for the federal agencies is 50 years (2005 to 2055).

The LCR MSCP is intended to avoid, minimize, and fully mitigate the incidental take of the covered species from the implementation of the covered activities to the maximum extent practicable. The EIS will evaluate operational interactions without altering LCR MSCP commitments. The LCR MSCP is being revisited in a separate process that will be finalized following the completion of this NEPA process.

1.9.4 Colorado River Storage Project Upper Initial Units RODs

The 1956 CRSPA authorized construction of the CRSP "to initiate the comprehensive development of the water resources of the Upper Basin, for the purposes, among others, of regulating flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado

River Basin Compact, respectively, providing for the reclamation of arid and semiarid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the foregoing purposes…"

There are four initial storage units built as part of the CRSP. The Glen Canyon Unit is the farthest downstream. The three upper initial units are Flaming Gorge Unit in Utah, Wayne N. Aspinall Unit in Colorado (Blue Mesa, Crystal, and Morrow Point Dams), and Navajo Unit in New Mexico (see **Map 1-1**). The current RODs governing operations of these units were signed in 2006, 2012, and 2006, respectively. Each ROD sets a range of releases from the unit with the goal of meeting flow and/or temperature recommendations.

With the adoption of the 2019 DCP, which included the Drought Response Operations Agreement (DROA), a specific operational mechanism was established for releases from the CRSP Upper Initial Units, if needed, to protect Lake Powell elevations and the ability of the Upper Division States to meet Compact compliance obligations while exercising their rights to develop and utilize Colorado River water. Releases from the CRSP Upper Initial Units implemented to date pursuant to the DROA have occurred within the scope of the existing RODs for the respective facilities, including the 2026 DROA release occurring during the final year of the agreement.

This Final EIS evaluates alternatives that contemplate the potential continued use of the CRSP Upper Initial Units to release additional water if needed to protect critical infrastructure at Glen Canyon Dam in a manner intended to remain within the scope of those existing RODs. While the Secretary will consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the CRSP Upper Initial Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes stated in the CRSPA.

1.9.5 2007 Interim Guidelines

Spurred by an ongoing multi-year drought, decreasing system storage, and growing demands for Colorado River water, in December 2007, the Secretary approved the ROD for the 2007 Interim Guidelines. The Guidelines, which are in place for an interim period through 2026, provide operating criteria for Lake Powell and Lake Mead including provisions designed to provide a greater degree of certainty to water users about timing and volumes of potential water delivery reductions, and additional operating flexibility to conserve and store water in the system. The interim nature of the Guidelines provided the opportunity to gain valuable experience for the management of Lake Powell and Lake Mead under modified operations and improve the basis for making future operational decisions, whether during the interim period or after.

The Guidelines are comprised of four operational elements collectively intended to address the purpose and need. These elements are as follows:

- **Shortage Guidelines:** Determines those conditions under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead to the Lower Division States below 7.5 maf pursuant to the Consolidated Decree.

- **Coordinated Reservoir Operations:** Defines the coordinated operations of Lake Powell and Lake Mead to provide improved operation of these two reservoirs, particularly under low reservoir conditions. As described in Section XI.G.6. of the ROD, the objective of the operation of Lake Powell and Lake Mead is "to avoid curtailment of uses in the Upper Basin, minimize shortages in the Lower Basin and not adversely affect the yield for development available in the Upper Basin."
- **Storage and Delivery of Conserved Water**: Allows for the storage and delivery, pursuant to applicable federal law, of conserved Colorado River System and non-System water in Lake Mead to increase the flexibility of meeting water use needs from Lake Mead, particularly under drought and low reservoir conditions. Delivery of water previously conserved pursuant to the 2007 Interim Guidelines will continue beyond 2026 per the provisions of the 2007 Interim Guidelines and the DCP.
- **Surplus Guidelines:** Determines those conditions under which the Secretary may declare the availability of surplus water for use within the Lower Division States. Modifies the substance of the ISG existing at the time the Guidelines were adopted by extending the term from 2016 to 2026 and terminating the most permissive provision.

Except for the special provisions described in Section XI.G.8. of the ROD, the Guidelines remain in effect through December 31, 2025 (through preparation of the 2026 AOP).

1.9.6 Operation of Glen Canyon Dam – Long-Term Experimental and Management Plan

In contrast to the annual releases determined through the Interim Guidelines, LTEMP determines sub-annual releases from Glen Canyon Dam. LTEMP identifies specific options for dam operations (including hourly, daily, and monthly release patterns), non-flow actions, and appropriate experimental and management actions that meet the Grand Canyon Protection Act's requirements and maintain or improve hydropower production to the greatest extent practicable, consistent with improvement of downstream environmental and cultural resources, including those of importance to tribes. While the Post-2026 process will consider LTEMP's implications for Glen Canyon Dam management, it will not modify decisions made in the LTEMP ROD.

1.9.7 2019 Colorado River Drought Contingency Plans

Consistent with and pursuant to provisions in the 2007 Seven States' Agreement and the 2007 Interim Guidelines, Reclamation and the Basin States have regularly consulted regarding various issues that have arisen during implementation of the 2007 Interim Guidelines. In 2019, recognizing that those relying on water from the Colorado River system faced increased individual and collective risk of temporary or prolonged interruptions in water supplies, with associated adverse impacts on the society, environment, and economy of the Basin, the Basin States agreed that it was necessary and beneficial to pursue additional actions beyond those contemplated in the 2007 Interim Guidelines to reduce the likelihood of reaching critical elevation levels in Lake Powell and Lake Mead through 2026. Two DCPs were developed: the Upper Basin Drought Contingency Plan (Upper Basin DCP), which affects operations above Lee Ferry, and the Lower Basin Drought Contingency Plan (Lower Basin DCP), which affects operations below Lee Ferry. The Agreement Concerning Colorado River Drought Contingency Management and Operations is an overarching agreement between the Basin States and

the Department where the parties agree to consultative and cooperative processes during implementation of the Upper Basin DCP and the Lower Basin DCP, similar to the 2007 Seven States' Agreement. The 2019 DCP is supplemental to and in furtherance of the goals of the 2007 Interim Guidelines.

While most provisions of the 2019 DCP expire at the end of 2026, certain provisions related to intentionally created surplus (ICS) recovery, recovery of 2026 DROA release volumes, and Upper Basin demand management opportunities extend beyond 2026. These include provisions for the delivery of ICS in storage upon expiration of the DCP and continued authorization to make capacity in the CRSP Upper Initial Units available at no charge in accordance with the terms of the Upper Basin Demand Management Storage Agreement. The alternatives in this Final EIS contain modeling assumptions regarding the delivery of pre-2027 ICS that are in accordance with these provisions and provide additional flexibilities. Additionally, some alternatives contain general assumptions about Upper Basin conservation and storage that could potentially be realized through demand management-type programs.

1.10 Draft EIS Public Review, Comment Summary, and Changes Between Draft and Final EIS

A Notice of Availability of the Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead Draft EIS (see **Appendix Q**) was published in the *Federal Register* on January 16, 2026, which initiated a 45-day public review and comment period that ended March 2, 2026.

Reclamation received 18,153 submissions during the Draft EIS comment period. Of the submissions, 7 were from state government entities, 23 from tribes, 4 from federal agencies, 28 from non-government organizations, 76 from local entities, 3 from academic or research institutions, 5 from elected officials, 21 from resource sector or business interests, and the remainder were from individuals. Reclamation identified 23 form letters; 11,992 submittals had identical text to one of the 23 form letters and 5,298 had unique text in addition to the form text. Reclamation noted 52 submittals as duplicates and only reviewed them once. Unique submissions are available on the project website, and all public comments are retained in the project record.

All submissions received during the Draft EIS public review period were recorded and reviewed to identify substantive comments. Given the high number of substantive comments, and in accordance with Department guidance (DOI NEPA Handbook 2026, Appendix Section 1), substantive comments were entered into a database and organized into themes so that similar comments could be reviewed and addressed together. **Appendix R** describes these themes and Reclamation's response.

Based on public input and continued stakeholder coordination, Reclamation revised this Final EIS and incorporated a Preferred Alternative, which is carried throughout the Executive Summary, EIS, Appendices, and Technical Appendices. Notable changes include the following:

- Inclusion of quantitative analysis of hydropower economic rates and recreation visitation
- Revised initial reservoir condition assumptions in modeling to reflect the "Dry" initial condition assumptions only

- Improved consistency and clarity in Decision Making under Deep Uncertainty (DMDU) descriptions and use of modeling results, including clearer discussion of uncertainty
- Added emphasis on the first decade of potential resource impacts to align with the key period of performance of the Preferred Alternative
- Revised Chapter 3 resource sections to clarify assumptions, methods, and conclusions, and improve readability through clearer organization, plain language, and reduced repetition
- Updated figures, tables, and appendices to maintain internal consistency across volumes
- Statistical summary tables contained within resource technical appendices were moved to the end of the applicable appendix to improve readability and document flow

Additional updates were made to appendices and supporting information. **Appendix P** was added to summarize consultation and coordination efforts between Reclamation and Basin Tribes. **Appendix Q** was added to document all *Federal Register* notices issued for the process, and **Appendix R** was added to summarize comment themes and Reclamation's responses. **Appendix S** was added to provide descriptions of the alternatives analyzed in the Final EIS. **Appendix T** was added to include a preliminary description and analysis of the anticipated first operating interval covering 2027-2028. The List of Preparers was substantially updated to reflect cooperating agency participation and other revisions made during preparation of this Final EIS. Figures, tables, appendices, and supporting information were updated throughout the document to maintain internal consistency across volumes.

Chapter 2. Description of Alternatives

The alternatives analyzed in this Final EIS include a broad range of operational elements incorporating over 4 years of input provided by stakeholders and the public and received through consultations with the Basin States and tribes. During this timeframe, Reclamation and the Department have engaged extensively with the Basin States to facilitate an agreement among the seven Basin States and the Secretary on various aspects of post-2026 operations for consideration in this NEPA process. Despite this extensive engagement, a long-term consensus-based approach to Basin reservoir operations has not yet been achieved.

In the absence of a long-term consensus-based approach, Reclamation has developed a Preferred Alternative and analyzed it in this Final EIS. As described in **Section 2.4**, the Preferred Alternative is a 10-year decision framework. The decision framework does not establish specific reservoir operating guidelines; rather, it provides the structure within which operating guidelines would be developed, reviewed, and periodically updated through 2036.

The decision framework in the Preferred Alternative offers a vehicle for continued work toward sustainable water management in the Basin. It provides continuity following the expiration of the 2007 Interim Guidelines; establishes transparency and predictability for future decision making; preserves flexibility to respond to changing hydrology and evolving Basin circumstances; facilitates incorporation of future Basin consensus recommendations; and is consistent with applicable federal law.

This chapter summarizes the alternatives development process, describes the Preferred Alternative, provides a summary of all other alternatives analyzed in this Final EIS, and summarizes the performance tradeoffs between alternatives. Additional detail on these alternatives, including those considered but eliminated from detailed analysis is provided in **Appendix S**, Additional Description of Alternatives.

2.1 Development of Alternatives

The goal of the alternatives development phase for this Final EIS was to develop a reasonable and broad range of alternatives for managing the Colorado River system and its resources. The objectives associated with analyzing a sufficiently broad range of alternatives are two-fold:

1. Ensuring that decision-makers and the public are informed of all potential impacts and tradeoffs of different operational approaches
2. Providing analysis for the four operational elements that are the basis for operating guidelines that may eventually be developed under the Preferred Alternative

The process of developing the range of alternatives was informed by solicitation of input and extensive collaborative engagement with stakeholders throughout the Basin. This took place over a two-and-a-half-year period beginning with publication of the Scoping Report in October 2023 (as

described in **Section 1.5**) through publication of this Final EIS. To facilitate public input on and understanding of the alternatives, from December 2023 through March 2026 Reclamation supported access to the Post-2026 Operations Exploration Web Tool. This Web Tool was an online platform developed to allow stakeholders, interested parties and the public to independently or collaboratively design, model and explore a wide range of creative operational strategies. Use of the platform was not considered formal input to the Post-2026 Process, but insights from the 500-plus operational strategies entered into the platform were used to inform alternatives.

During the public involvement periods and the rest of the alternatives development process, Reclamation received considerable input from the Basin States, many Basin Tribes, conservation organizations, other federal agencies, other stakeholders, and members of the public. Input submitted ranged from detailed proposed alternatives to operational concepts and principles. Throughout the alternatives development phase, Reclamation met continuously with states, tribes, and other partners to review and discuss their input. For those proposals containing sufficient detail to be considered as a full alternative or a major component of an alternative, Reclamation worked extensively with these entities to not only understand and gather additional information, but also to model and perform preliminary analyses of their proposals to facilitate refinements.

Reclamation continued to inform the public on the status of alternatives development by conducting a public webinar in October 2024[1] and publishing an Alternatives Report (Reclamation 2025a) documenting the preliminary alternatives as of January 2025. On January 9, 2026, the EPA published a notice in the *Federal Register* (91 *Federal Register* 2131) announcing the availability of the Draft EIS and beginning a public comment period that ran through March 2, 2026. The Draft EIS analyzed five alternatives to capture a broad range of operational concepts and potential environmental impacts:

- No Action Alternative (discussed in **Section S.1**)
- Basic Coordination Alternative (discussed in **Section S.2**)
- Enhanced Coordination Alternative (discussed in **Section S.3**)
- Maximum Operational Flexibility Alternative (discussed in **Section S.4**)
- Supply Driven Alternative (discussed in **Section S.5**)

As discussed in more detail in **Section 2.4**, this Final EIS contains an additional alternative that the Department has identified as the Preferred Alternative.

The alternatives analyzed in the Draft EIS were informed by input from the Basin States, Basin Tribes, and other stakeholders referenced above, though they do not include all proposals submitted as standalone alternatives. Prior to the publication of the Draft EIS, Reclamation performed preliminary modeling of the initial (March 2024) and revised (December 2024 and January 2025) proposals submitted separately by the Upper Division States and Lower Division States and concluded that each lacked an appropriate basis for the comprehensive and coordinated operations of Lake Powell and Lake Mead. After continued work with all seven states throughout the spring and summer of 2025, the concept that became the Supply Driven Alternative was actively being considered by all states but had

[1] Webinar presentation material is available here: https://www.usbr.gov/ColoradoRiverBasin/documents/post2026/P26_Public_Status_Update_Webinar_10-10-24_508.pdf.

not achieved full agreement. Because there was no consensus-based alternative, the Draft EIS attempted to capture the state of discussions through inclusion of the Supply Driven Alternative but did not identify a preferred alternative. After publication of the Draft EIS, coordination with the States continued although the discussion had moved away from the concept of the Supply-Driven Alternative.

In addition to the individual state comments submitted on the Draft EIS that contained proposed operational strategies, the Upper Division States and Lower Division States submitted additional proposals in May 2026 after the publication of the Draft EIS. The proposal submitted by the Lower Division States described a 2-year set of operating guidelines through 2028 as a bridge to allow future opportunity to reach a consensus-based long-term solution. The Preferred Alternative identified in this Final EIS incorporates concepts from the States' proposals and tribal input and leaves open the opportunity for Basin entities to subsequently arrive at a consensus-based path forward. Should no consensus emerge, the Preferred Alternative ensures that the Secretary will have the flexibility to make necessary operational decisions.

2.2 The Four Operational Elements Included in Each Alternative

In consideration of the input received during pre-scoping and scoping, and to meet the purpose and need described in **Section 1.3**, Reclamation identified four operational elements that make up each alternative described below.[2] Each alternative represents a different option for implementing the proposed federal action described in **Section 1.2**. Descriptions of the alternatives will be based on their implementation of each element. For a summary of key features of each alternative, see **Section 2.5**, Summary Comparison of Alternatives. **Appendix A**, Colorado River Simulation System (CRSS) Model Documentation, describes detailed modeling assumptions for the alternatives.

Determination of deliveries to Mexico is not a part of the proposed federal action. Any such determination would be made in accordance with the 1944 Water Treaty. Nevertheless, modeling assumptions regarding water deliveries to Mexico are necessary in order to analyze the potential impacts on hydrologic and other environmental resources. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

2.2.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

This element addresses the adoption of guidelines that would identify those circumstances under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead to the Lower Division States below 7.5 maf, pursuant to the Consolidated Decree (*Arizona v. California*, 547 U.S. 150). It also addresses the definition of conditions under which the Secretary may declare the availability of surplus water for use within the Lower Division States. Article III of the

[2] The operational elements include modeling assumptions but do not necessarily describe all implementation details that would be developed should an alternative be finalized and adopted. Impacts are addressed in subsequent chapters.

LROC lists some relevant factors for determining available water, including storage in Lake Mead, expected inflows, and historical streamflow.

The primary purpose of this element is the distribution of water supplies during drought and low reservoir conditions. While Lake Powell and Lake Mead have large storage capacities, recent years have shown that careful management of available supply is key to ensure sufficient supplies are available to meet future water demands. The alternatives present a range of shortage guidelines, from aggressive shortages to reductions slightly higher than the maximum volumes included in current policies, different distributions in the Lower Division States (including priority-based and other approaches), and a variety of criteria to trigger reductions.

The specified shortage volumes in each alternative include modeling assumptions related to reductions in water deliveries to Mexico in order to analyze the potential impacts on hydrologic and other environmental resources. These modeling assumptions are identical under all alternatives.[3] **Appendix K**, Sensitivity Analysis – Effects of Modeling Assumptions with Regard to Future Water Deliveries to Mexico, compares the effects of varied assumptions.

This element also provides for the distribution of water above 7.5 maf when reservoir conditions support it.

2.2.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

This element addresses adoption of guidelines for the coordinated operation of Lake Powell and Lake Mead to potentially improve operation of these two reservoirs. The LROC specify coordination at high elevations through the equalization of storage in Lake Powell and Lake Mead, as nearly as practicable.

Operations under the current guidelines have provided valuable experience related to the implications of coordinating Lake Powell and Lake Mead. The effects of coordination on each reservoir depend on other aspects of an alternative, for example, shortage triggers and volumes, so the degree to which coordination improves operations is context specific. The alternatives range from highly coordinated distribution of storage to minimal coordination.

2.2.3 Storage and Delivery of Conserved System and Non-System Water

This element addresses the adoption of guidelines for the storage and delivery of conserved Colorado River system and non-system water in Lake Powell and Lake Mead, pursuant to applicable law, to increase flexibility in meeting water use needs while maintaining reservoir storage above critical elevations.

Extended drought, low reservoirs, and hydrologic variability from year to year create challenges when trying to plan for water supply and protect critical elevations. Mechanisms that offer water users flexibility to conserve and/or augment water supplies can increase stability of the reservoirs, thereby reducing the need for and mitigating the impacts of large shortages. The alternatives represent a wide range of approaches to this element, including no new conservation mechanism, to moderately sized pools in Lake Powell and Lake Mead open to users within the Upper and Lower Basins, respectively, to

[3] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

large, inclusive pools that may be flexibly stored in either reservoir to maximize their benefit to the system.

While delivery of existing ICS is available after 2026 pursuant to existing and any new agreements, Reclamation may establish guidelines for administration of a new ICS program and/or storage mechanisms, including requirements for verification of the conservation action and water accounting procedures.

2.2.4 Additional Activities Above Lake Powell

This element addresses additional activities above Lake Powell including releases from the CRSP Upper Initial Units[4] within their respective RODs to increase elevations at Lake Powell and conservation by Upper Basin water users to support critical elevations at Lake Powell and other important system goals.

Since the adoption of the DCP, the Basin has recognized the importance of developing a framework to formally employ resources above Lake Powell to mitigate the potential for critical impacts on infrastructure. These alternatives represent various levels of within-ROD releases from CRSP Upper Initial Units (see **Section 1.9.4** and **Map 1-1**) and Upper Basin conservation, and different assumptions about consideration of these activities in broader operations.

2.3 Authorities to Implement Alternatives

The Secretary has the vested authority and responsibility to operate the System through coordinated operations, including the ability to respond to exigent and emergency conditions, pursuant to applicable federal law, the Decree, contractual obligations, and other elements of the Law of the River.[5] Since the late 1990s, management of the river has historically been based on Secretarial authority along with tools that are founded on agreements among Basin water users (e.g., interstate water banking, ICS and forbearance, etc.). In most cases, Reclamation's authority has been sufficient to fully implement the agreements. In contrast, however, specific operational mechanisms negotiated as part of the 2019 DCP required congressional legislation[6] to fully implement.

The alternatives in this Final EIS are designed to cover a wide range of potential outcomes with respect to post-2026 operations; accordingly, they incorporate components that are within existing authorities along with components that would require new authorities and/or new agreements among Basin water users to fully implement.

[4] Flaming Gorge, Blue Mesa (the most upstream facility of the Aspinall Unit, which serves as its primary storage reservoir), and Navajo reservoirs.

[5] This Final EIS analyzes potential operations to improve coordinated operations under dry hydrology that are designed to reduce the need for emergency operations. However, the need to perform emergency or other necessary operations remains, and the Department reserves its authorities to perform such operations, which could include operation of UIUs outside of RODs, reduction of Glen Canyon Dam releases, and greater Lower Basin shortages. Specific emergency, or other necessary operations, are not proposed in this document because the conditions around such potential operations are too speculative at this time. If such conditions arise, operational decisions and notifications would be made at that time based on the then-current conditions with appropriate levels of analysis.

[6] The Colorado River Drought Contingency Authorization Act was passed on April 16, 2019, directing the Secretary to implement the 2019 DCP.

2.4 Preferred Alternative

The Preferred Alternative is a 10-year decision framework through 2036. The decision framework establishes operational principles, sideboards (key thresholds and ranges for operational elements), and a process that would govern development and issuance of operating guidelines covering anticipated 2-year intervals, unless consensus-based agreements provide for a longer duration. The framework does not establish specific operating guidelines; rather, it provides the structure within which operating guidelines would be developed, reviewed, and periodically updated. The framework (principles, sideboards, and process) would remain constant through 2036, unless modified through future federal action and appropriate environmental compliance.

The choice of a 10-year period in the Preferred Alternative is a duration contemplated in the Draft EIS but shorter than the duration of recent operating guidelines. In 2023, the Proposed Federal Action contemplated adopting successor operating guidelines for approximately 20 years, which was identified as an appropriate length of time to gain operational experience and reflected the expectation that the Basin would reach consensus on a long-term operational approach. At the time the Draft EIS was published, that outcome was still being pursued. In the absence of such consensus, and given the uncertainty facing the Basin, the Department has determined that rather than imposing prescribed operating guidelines that would be in place for 20 years, a different approach was needed. Thus, the Department selected a 10-year decision framework that provides certainty regarding the decision process while preserving flexibility to adapt to changing conditions. A 10-year duration also provides sufficient time to gain operational experience, thereby informing future operational and water management decisions.

As of the date of this Final EIS, it is anticipated that the first operating interval would cover 2027–2028. Reclamation worked extensively with stakeholders to develop guidelines that align with the operational principles and sideboards. For the purpose of describing the potential upcoming operating guidelines and their associated impacts, a preliminary description and analysis of those anticipated operating guidelines is included in **Appendix T**.

2.4.1 Rationale for Selecting the Preferred Alternative

Since 2021, Colorado River operations have included a series of extraordinary operations designed to bolster reservoir elevations and protect the ability of infrastructure at Glen Canyon Dam to continue reliable operations in response to extremely low hydrologic conditions. Despite all of these measures, and compounded by uncertain future hydrologic conditions, the risk to the system has never been greater. The prevalence of extraordinary activities and the state of the system demonstrate the great need for flexibility and adaptation. At the same time, structure and transparency are needed to provide predictability for Basin stakeholders.

Consensus-based approaches have provided stability for the system for decades, including when extraordinary measures have been needed. The Department and Reclamation engaged extensively with the Basin States, Basin Tribes, and other interested parties in pursuit of developing consensus-based long-term operational guidelines. Unfortunately, as of the publication of this Final EIS, consensus on long-term operations has not been reached. Basin entities continue to work toward consensus and, given how important consensus-based agreements have been in the Basin, the Department is

committed to preserving the opportunity to implement potential future consensus agreements within the Preferred Alternative. Should no consensus emerge, the Preferred Alternative ensures that the Secretary will have the flexibility to make necessary operational decisions.

The Preferred Alternative strikes a balance between flexibility and predictability given unprecedented hydrologic and system conditions and the potential for considerable impacts on water users. It is a reasonable approach to meeting the purpose and need described in **Section 1.3**. Analysis of the operational sideboards in **Section 2.6** demonstrates that, while there are inherent performance tradeoffs among resources that benefit from different fundamental system elements—storage in each reservoir, dam releases, river flows, and water deliveries—the Preferred Alternative, as analyzed in the Representative Preferred Alternative (described in **Section 2.4.3**), appropriately balances the tradeoffs and achieves more robust performance than previous operations.

The decision framework establishes a transparent and structured process guided by operational principles that allows Reclamation and stakeholders to adapt and respond to uncertain future conditions and extremely low reservoir elevations. This flexibility allows for the recognition of evolving Basin circumstances and for more robust performance through development of innovative and adaptive operational mechanisms.

2.4.2 Operating Guidelines, Operational Principles, Operational Sideboards, and Process

2.4.2.1 Operating Guidelines

Operating guidelines are the objective criteria that determine the operations of Lake Powell and Lake Mead for the anticipated 2-year interval. For each interval, the framework process would be carried out to develop and issue operating guidelines in accordance with the principles and sideboards described below. The operating guidelines would be adopted through the issuance of a decision document published in the *Federal Register*. Once issued, the operating guidelines would be implemented through Annual Operating Plans.

During the implementation of each set of guidelines, the process to develop subsequent guidelines would begin. Each set of operating guidelines would be informed by the operational principles, consider the performance of the previous operating guidelines, and incorporate additional agreements that may be reached during the duration of the decision framework, such as consensus agreements among states and other parties and/or tribal water rights settlements. Before the issuance of new operating guidelines, a review would be conducted to ensure that the potential impacts of such operating guidelines are within the range of impacts analyzed in this NEPA process.

Throughout the period of the decision framework, it is the intent that the operating guidelines would implement the LROC by providing objective criteria for coordinated operations, while recognizing operations to respond to extraordinary circumstances due to hydrologic conditions may be warranted, consistent with applicable federal law.

As of the date of this Final EIS, the first set of operating guidelines are anticipated to be issued in July 2026 and are anticipated to cover 2027–2028.

2.4.2.2 Operational Principles

The decision framework's operational principles are fundamental objectives and considerations that reflect Reclamation's mandate to protect the Colorado River system infrastructure, acknowledge the Secretary's authority to operate the system and take protective actions when necessary, and promote reaching consensus operations whenever possible.

Elevating these principles ensures that operating guidelines adopted under the framework adhere to fundamental management priorities and provide a basis for review and reflection as new operating guidelines are developed.

The operational principles are listed below:

1. **Operations should be responsive to hydrology.** Annual operations and mid-year adjustments that account for evolving supply conditions should be adopted to ensure a flexible, adaptive approach to management.
2. **Critical federal infrastructure must be protected through practical and deliberate operations**. When Lake Powell is projected to fall below elevation 3,500 feet or when Lake Mead is projected to fall below elevation of 1,000 feet, processes and tools will be used to manage risks to infrastructure and prevent damage to federal facilities of regional and national importance. These elevations reflect current understanding of these facilities but do not preclude the identification of alternate or additional critical elevations.
3. **Operating guidelines should implement the LROC while also providing directions to address extraordinary circumstances**. Operating guidelines will provide objective criteria for operating under low reservoir conditions within the bounds of the LROC but may also provide for temporary operational actions that are not otherwise provided for under the LROC when necessary to protect critical federal infrastructure in accordance with applicable federal law.
4. **Operating guidelines should prioritize consensus-based recommendations**. The Department will support efforts to achieve consensus agreements that appropriately provide benefits to multiple parties, that offer innovative, inclusive solutions to operational and management challenges, and that are sufficiently protective of the system. Should such agreements arise, they will be prioritized as new operating guidelines are developed and adopted. In the absence of consensus-based arrangements, the Secretary will take necessary management actions, consistent with applicable federal law.

2.4.2.3 Operational Sideboards

The decision framework's operational sideboards are key thresholds and ranges for operational elements that create boundaries for the development of each set of operating guidelines and provide a basis for environmental compliance for the duration of the decision framework. The sideboards defined in **Table 2-1** were chosen to appropriately balance tradeoffs among resources and ensure that the Department would have the flexibility and environmental compliance to operate in accordance with the operational principles given future hydrologic uncertainty.

Table 2-1
Operational Sideboards for the Preferred Alternative

Operational Element	Operational Ranges
Lower Basin Shortage Guidelines	Up to 3.0 maf to provide protection of critical infrastructure at Hoover Dam in dry hydrologic conditions The allocation of shortages would be based on applicable law, including the Consolidated Decree. Deviation from applicable law would occur only if water entitlement holders have reached voluntary arrangements Consultation would occur if projected Lake Mead elevation < 1,000 ft to determine potential additional reductions to Lower Basin water deliveries
Coordinated Reservoir Operations	5.0 maf to 12.0 maf Lake Powell WY releases to provide protection for critical infrastructure at Glen Canyon Dam and sufficiently high releases necessary to prevent spill avoidance releases Consultation would occur if projected Lake Powell elevation < 3,500 ft to determine potential additional actions
Storage and Delivery of Conserved System and Non-system Water	Lake Powell: up to 3.0 maf Lake Mead: up to 8.0 maf (supports existing ICS, new ICS-type program, conservation pools, and exchange mechanisms)
Lower Basin Surplus Guidelines	Up to 500.0 kaf in addition to Flood Control and Quantified Surplus
Additional Activities Above Lake Powell	Potential for maximum use of CRSP Upper Initial Units within their respective RODs to release additional water if needed to protect critical infrastructure Voluntary Upper Basin contributions up to 200.0 kaf per year subject to hydrologic conditions

2.4.2.4 Process

Each set of operating guidelines would be implemented and evaluated through a process during which Reclamation would work with stakeholders to seek consensus, align with operational principles and sideboards, and account for system conditions, hydrology, and other Basin developments. This process is illustrated through an example schedule of activities and determinations during the potential 2027–2028 operating guidelines interval outlined in **Table 2-2**. Two years are anticipated to be appropriate due to the current drier hydrological conditions and low reservoir elevations of the system.

Table 2-2
Example Operating Guidelines Process, 2026-2028

Month and Year	Reclamation Actions or Activities by Water Year (WY)
July 2026	• Anticipated issuance of Operating Guidelines pursuant to ROD
August 2026	• Implement WY 1 operations through AOP
August 2027	• Implement WY 2 operations through AOP

Month and Year	Reclamation Actions or Activities by Water Year (WY)
October 2027	• Review current Operating Guidelines and develop considerations for the next set of Operating Guidelines
November 2027	• Release review and considerations for the next set of Operating Guidelines
November 2027 – March 2028	• Engage and consult with stakeholders regarding the next set of Operating Guidelines • Develop preliminary proposed Operating Guidelines, applying operational principles and sideboards
March 2028	• Release preliminary Operating Guidelines
May 2028	• Consensus recommendations on Operating Guidelines due
May – June 2028	• Finalize Operating Guidelines, perform analysis and necessary consultations
June 2028	• Release upcoming Operating Guidelines • Initial AOP consultation on next WY's operations (per upcoming Operating Guidelines)
July 2028	• Conduct compliance checks on upcoming Operating Guidelines • Issue Federal Register Notice with Operating Guidelines
August 2028	• Implement WY 3 operations through AOP

Subsequent periods would follow the same process of implementing, reviewing, engaging, and issuing new operating guidelines.

2.4.3 Representation of the Four Operational Elements

In contrast to the specified operations under the other alternatives in this chapter, the Preferred Alternative is designed to create the opportunity for subsequent decision making; because of this distinction, it is appropriate to include a modeling representation of operating guidelines that may be developed under the Preferred Alternative. The sideboards provide a basis for understanding the range of potential impacts, and analyzing these potential impacts provides a necessary and instructive comparison to the other alternatives included in this Final EIS. Taken together, the representation of the operational elements described below is referred to and analyzed in this Final EIS as the "Representative Preferred Alternative." The Representative Preferred Alternative is a set of modeling assumptions designed around the Preferred Alternative sideboards to approximate the range of operating guidelines that may be adopted for each interval during the 10-year framework. The specifications in the operational elements below reflect how the Representative Preferred Alternative was modeled; exact operations would be subject to the guidelines in place during each interval and would adhere to consultation triggers as described in **Table 2-1**. The modeling assumptions do not represent implementation details (e.g., use of projections) that would be identified as specific operating guidelines are developed through the decision framework process.

Modeling in this Final EIS that captures the sideboards, and the analysis of the potential impacts, provides environmental compliance for decisions made consistent with the decision framework.

2.4.3.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

2.4.3.1.1 Shortage Conditions

This alternative models shortages of up to 3.6 maf (including assumptions about reductions to Mexico) and two different approaches to distributing shortages are applied. Two different approaches for distributing shortage are modeled in order to analyze the impacts of the proposal received on May 1, 2026, from the Lower Division States regarding the distribution of shortage in 2027 and 2028.

In 2027 and 2028 shortage volumes up to 1.5 maf are distributed using the approach developed by the Lower Division States and shortage volumes above 1.5 maf up to 3.6 maf are distributed using the priority system.[7] In 2029 through 2060, all volumes of shortage are distributed using the priority system. **Table 2-3** and **Table 2-4** show how shortage volumes are divided among the states and Mexico for each time period.

The shortage guidelines are summarized below and shown in **Figure 2-1**.

Table 2-3
2027–2028 Shortage Distribution,
Representative Preferred Alternative

Entity	Shortage (%) from 0 to 300 kaf	Shortage (%) from 300 to 1,500 kaf	Total Shortage (kaf) when Lower Basin-wide Shortage is 1,500 kaf	Shortage (%) 1,500 kaf to 2,344 kaf	Shortage (%) 2,345 kaf to 3,600 kaf
Arizona	80.00	43.33	760	76.26	31.10
California	0	36.67	440	0	45.16
Nevada	3.33	3.33	50	7.08	7.08
Mexico	16.67	16.67	250	16.67	16.67

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

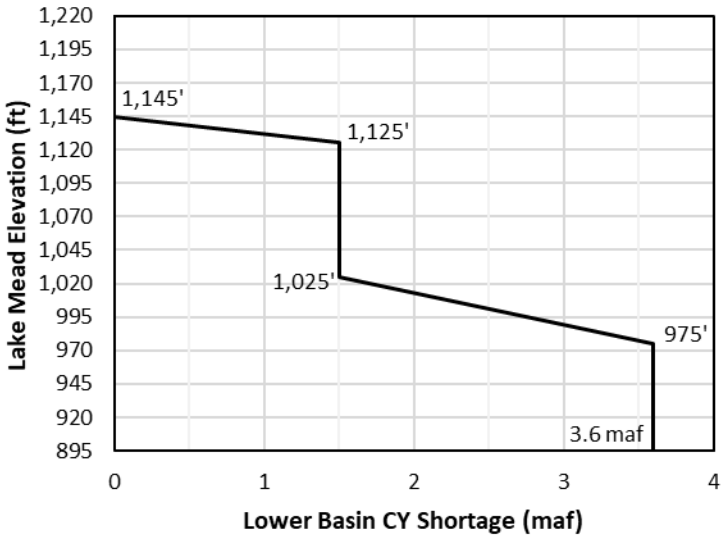
[7] As noted in **Section 2.4**, the anticipated guidelines for the first operating interval as of publication of this Final EIS are preliminary. Modeling assumptions for 2027–2028 regarding shortage distribution reflect the May 1, 2026, Lower Division States proposal. As described in **Table 2-1**, Operational Sideboards for the Preferred Alternative, absent voluntary arrangements, the distribution of shortages would be based on applicable law (i.e., the priority system). This distribution is modeled in the Representative Preferred Alternative for years 2029 and beyond. Both distribution methods are documented and analyzed in **Appendix C**, Shortage Allocation Model, and **Chapter 3**. Regarding maximum shortage volume, modeling assumptions provide for reductions above the 1.25 maf maximum if needed to avoid critically low elevations at Lake Mead.

Table 2-4
2029-2060 Shortage Distribution, Representative Preferred Alternative

Entity	Shortage (%) from 0 to 1,814 kaf	Shortage (%) from 1,815 to 3,600 kaf
Arizona	77.40	25.77
California	0	51.63
Nevada	5.93	5.93
Mexico	16.67	16.67
Total	**100**	**100**

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Figure 2-1
Shortage Guidelines to Reduce Deliveries from Lake Mead, Representative Preferred Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

2.4.3.1.2 Surplus Conditions

Volumes above normal apportionment are distributed when criteria are met in Lake Mead for a Domestic Surplus Condition, a 70R Surplus Condition or a Flood Control Surplus Condition.[8, 9] A Domestic Surplus is determined anytime the January 1 Lake Mead pool elevation is at or above 1,165 feet and Flood Control or 70R Surplus is not triggered. Depending on Lake Mead's physical pool elevation, up to 500.0 kaf of Domestic Surplus volume is distributed.

2.4.3.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

The WY release volume from Lake Powell determined on October 1 ranges from 6.0 maf to 12.0 maf. If Lake Powell is projected to decline below elevation 3,500 feet, the WY release volume is reduced to as low as 5.0 maf to protect critical elevations at Lake Powell.

2.4.3.2.1 Primary Operations

WY releases from Lake Powell would be based on the observed October 1 elevation[10] as depicted in **Figure 2-2**.

2.4.3.2.2 Coordination at High Elevations

A determination to potentially increase releases for the purpose of equalizing storage between Lake Powell and Lake Mead is made for the upcoming year if, on October 1, the net storage of all CRSP reservoirs exceeds the 602(a) storage volume, computed using the parameters from the 2007 Final EIS. **Appendix J**, Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage, describes the 602(a) storage calculation and documents the parameters used in the 2007 calculation, which are also used in this alternative. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values. Under Equalization, Lake Powell would release a minimum of 12.0 maf and may release more to balance storage with Lake Mead (see **Appendix A**, CRSS Model Documentation, for details).

2.4.3.2.3 Infrastructure Protection and Other Considerations

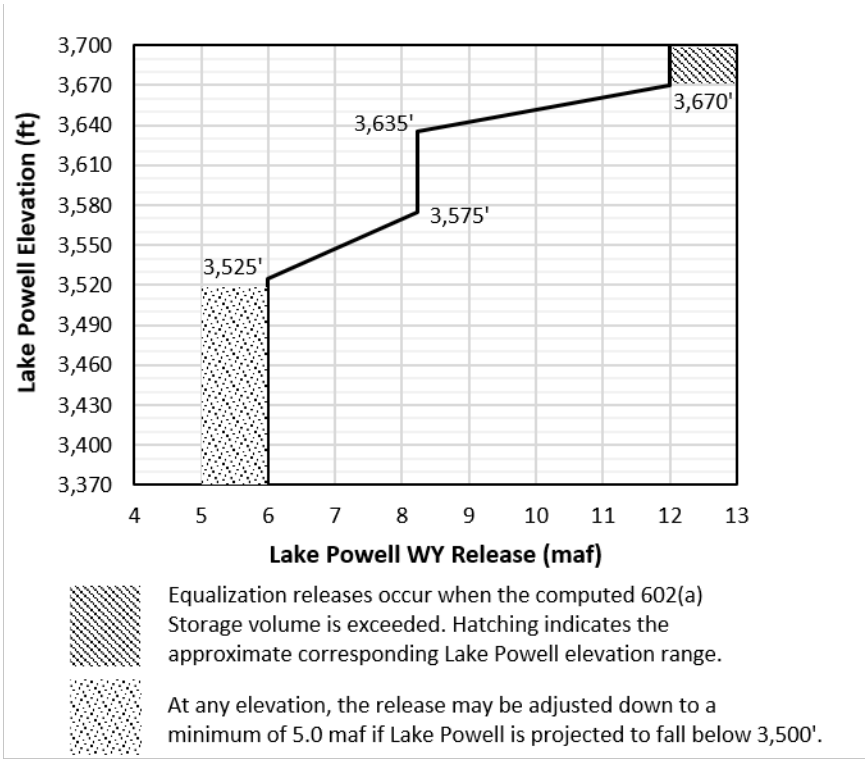
If Lake Powell is projected to fall below 3,500 feet within the WY, the WY release is reduced to prevent this from occurring, subject to a minimum WY release of 5.0 maf.

[8] The 70R Strategy is a modeling approach used by Reclamation since the 1980s to understand the need to distribute additional water, and it was documented in the 2007 Final EIS. Under the strategy, a Surplus Condition is based on the system space requirement at the beginning of each year. Based on the 70th percentile historical runoff, a normal 7.5 maf delivery to the Lower Division States, the Upper Basin scheduled use, and Lake Powell and Lake Mead volumes at the beginning of the year, the volume of water in excess of the system space requirement at the end of the year is estimated. If that volume is greater than zero, a Surplus is declared.

[9] If flood control releases are anticipated to be required given the current inflow forecast, the Secretary declares Flood Control Surplus conditions for that year.

[10] While a mid-year adjustment is included in the operational principles for the Preferred Alternative, it was not incorporated into the Representative Preferred Alternative modeling assumptions when they were finalized due to then-ongoing discussions about how such a mechanism should be used to adjust Lake Powell's WY release. The modeling of the Representative Preferred Alternative is still a reasonable representation of the operational principles and sideboards. Although the mid-year adjustment can shift the timing of release volumes, modestly increasing or decreasing a given WY release with a likely corresponding adjustment in the opposite direction the following year, it would not change the range of WY releases across the analysis, which would remain within the sideboards of 5.0 to 12.0 maf.

Figure 2-2
Coordinated Operations of Lake Powell and Lake Mead, Representative Preferred Alternative



2.4.3.3 Storage and Delivery of Conserved System and Non-System Water

This alternative incorporates specific elements that are designed to provide enhanced flexibility and predictability for water users via a storage and conversion mechanism in Lake Powell and storage and delivery mechanisms in Lake Mead. The storage, conversion and delivery mechanisms include assumptions for contributions of consumptively used tribal water, which may require additional authorities.

Three pools capture a range of opportunities to store, convert and deliver water for the benefit of water users and the system: the Lake Powell mechanism, the water user-controlled Lake Mead mechanism, and the Lake Mead Federally Managed Water Resources Pool, which was informed by a group of Basin Tribes and would be established by Reclamation for Lower Basin-wide benefits. The design of these mechanisms supports proactive conservation and water user flexibility.

2.4.3.3.1 Lake Powell Mechanism

Water conserved by Upper Basin users would be stored in a pool in Lake Powell that could reach a maximum volume of 3.0 maf. Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool and to use their conserved water in intra- and interstate transactions with other Upper Basin users. Upper Basin Tribes would receive credit for the contribution of conserved consumptive use stored in the pool. Water in the Lake Powell conservation pool can be released if needed to meet the determined WY volume. Assumptions related to contributions to the Lake Powell conservation pool are described in **Section 2.4.3.4.1**.

2.4.3.3.2 Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 7.0 maf, which includes the storage of pre-2027 ICS. Annual total and state-based limits for conservation volumes and delivery of conserved water are presented in **Table 2-5**. All conserved water stored in Lake Mead would be included in determinations of equalization releases from Lake Powell and Lower Basin surplus and shortage volumes. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users.

Table 2-5
Volume Limitations of Storage and Delivery of Conserved Water, Representative Preferred Alternative

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery[2] (kaf)
Arizona	880	2,300	430
California	880	2,300	430
Nevada	100	900	140
Mexico[1]	500	1,500	200[3]
Total	**2,360**	**7,000**	**1,200**

1) Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
2) The Representative Preferred Alternative maintained the total U.S. annual delivery of 1.0 maf from the 2007 Interim Guidelines. For modeling purposes, to maximize reach impacts, and to integrate with other modeling assumptions, e.g., demand schedules, the state specific maximums were modified from those in the 2007 Interim Guidelines; this modeling assumption is not intended to determine any future state maximum delivery constraints.
3) The 1944 Water Treaty authorizes scheduled delivery of up to 200.0 kaf in excess of the 1.5 annual allotment to Mexico.

Water users could contribute and convert or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool. At the time the water is conserved, a one-time three percent system assessment would be applied, along with a one-time seven percent assessment allocated to the Federally Managed Water Resources Pool, for a total assessment of 10 percent.

Conversion and delivery of conserved water would be prohibited when Lake Mead begins the year with a physical pool elevation below 1,000 feet and would be limited to 50 percent of the maximum annual delivery/conversion volume when Lake Mead begins the year with a physical pool elevation between 1,000 and 1,025 feet. Additionally, when Lake Mead begins the year with a physical pool elevation above 1,125 feet, delivery and conversion of stored water would not be subject to a state's annual apportionment or Mexico's annual allotment.

2.4.3.3.3 Lake Mead Mechanism (Federally Managed Water Resources Pool)

The Federally Managed Water Resources Pool is a pool of water in Lake Mead established by Reclamation that is anticipated to be around 450.0 kaf, but could reach a maximum volume of 1.0 maf[11]. It could acquire water through multiple mechanisms involving acquisition of conserved consumptive use water including but not limited to ICS. Contents of the Pool would be included in determinations of Lake Powell equalization releases and Lower Basin surplus and shortage volumes.

Depending on final formulation, the Pool could be used for a range of purposes, including meeting federal firming or other federal delivery obligations pursuant to Congressionally authorized Indian water rights settlements[12] and providing limited offsetting of tribal water shortages as well as protecting federal infrastructure. Modeling assumptions related to logic for creation and use of Pool volumes can be found in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water. Delivery of water from the Pool would be prohibited when Lake Mead's elevation is below 1,000 feet. Additionally, annual contribution and delivery/conversion constraints could be outside the limits outlined in **Section 2.4.3.3.2**.

2.4.3.3.4 Treatment of Pre-2027 Intentionally Created Surplus

ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be transferred to the Post-2026 Lake Mead water user-controlled mechanism immediately and would be subject to all provisions described in the previous section.

2.4.3.4 Additional Activities Above Lake Powell

2.4.3.4.1 Upper Basin Conservation

Exact volumes of Upper Basin conservation over time are uncertain, but for the purposes of modeling, conservation up to a maximum volume of 200.0 kaf per year is included, with variable annual volumes based on hydrologic conditions. Conservation is modeled as a single lumped volume; no assumptions are made with respect to contributions from different entities or via specific activities.

2.4.3.4.2 Releases to Protect Glen Canyon Dam

This alternative would allow for potentially maximum use of the CRSP Upper Initial Units within their respective RODs to release additional water if needed to protect critical infrastructure at Glen Canyon Dam. Additionally, if Lake Powell's elevation is projected to go below 3,525 feet, CRSP Upper Initial Units would increase their releases within their RODs, contingent on hydrologic conditions. Reclamation would identify triggers for when additional Upper Basin actions would be required to protect critical infrastructure. Any volumes released for the protection of Glen Canyon Dam would begin to be recovered when Lake Powell is no longer projected to go below 3,525 feet by assuming that the CRSP Upper Initial Units return to their normal annual operating targets The frequency and volumes of the assumed releases to protect Glen Canyon Dam are assessed in **Appendix O**, Analysis of Powell Infrastructure Protection Releases.

[11] This volume has been proposed to accommodate future water use arrangements, which could include but would not be limited to conservation programs, contracts, and potential Indian water rights settlements.

[12] The Secretary is obligated to firm certain volumes of CAP non-Indian agricultural water provided as part of Indian water rights settlements to specific tribes in Arizona, including under Section 105(a) of the Arizona Water Settlements Act of 2004, Pub. L. 108-451, 118 Stat. 3478.

2.5 Summary Comparison of Alternatives

Preferred Alternative (Including Representation of Operational Elements)	The Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals, unless consensus-based agreements provide for a longer duration. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS, and each set of guidelines would be developed based on operational principles and fit within the framework's defined operational sideboards (thresholds and ranges for operational elements). The sideboards provide a basis for assumptions included in the Representative Preferred Alternative summarized in this table, which captures the range of operating guidelines that may be adopted during each interval. Lake Powell releases range from 5.0 maf to 12.0 maf depending primarily on Lake Powell elevation. Lower Basin shortages up to 3.6 maf (including assumptions about reductions to Mexico) are distributed using a combination of LB Priority (up to 1.5 maf, 2027-2028) and priority.				
	Shortage Guidelines to Reduce Deliveries from Lake Mead[3, 4]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)**	**Storage and Delivery of Conserved System and Non-system Water[3]**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
	• Shortages up to 3.6 maf (including assumptions about reductions to Mexico) • In 2027-2028, shortages up to 1.5 maf are distributed based on the distribution developed by the Lower Division States and shortages exceeding 1.5 maf are distributed based on priority (Approach 1 of the Supply Driven Alternative) • After 2028, shortages are distributed based on priority, unless agreements are reached • Consultation to determine additional reductions if projected Lake Mead elevation is less than 1,000 feet	• Lake Powell releases determined based on Lake Powell elevation unless equalization releases are required • Releases range from 5.0 to 12.0 maf, unless more is required for equalization releases • Consultation to determine additional actions if projected Lake Powell elevation is less than 3,500 feet	• Storage up to 7.0 maf in Lake Mead with additional 1.0 maf Federally Managed Water Resources Pool; included for purposes of determining Lower Basin surplus and Shortage Conditions, as well as equalization releases from Lake Powell • Storage up to 3.0 maf at Lake Powell; included for purposes of determining Lake Powell releases • Existing ICS converted to new mechanism immediately • Expanded flexibilities: interstate exchanges within each basin, new tribal mechanism	• Surplus determinations based on Lake Mead elevation at or above 1,165 feet, 70R (spill avoidance strategy) or Flood Control conditions	• Potential maximum use of CRSP Upper Initial Units within their respective RODs to release additional water if needed to protect critical infrastructure at Glen Canyon Dam contingent on hydrologic conditions • Trigger additional releases when projected Lake Powell elevation is less than 3,525 feet • Voluntary Upper Basin contributions up to 200.0 kaf per year subject to hydrologic conditions

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[4] As noted in **Section 2.4**, the anticipated guidelines for the first operating interval as of publication of this Final EIS are preliminary. Modeling assumptions for 2027-2028 regarding shortage distribution reflect the May 1, 2026, Lower Division States proposal. As described in **Table 2-1**, Operational Sideboards, absent voluntary arrangements, the distribution of shortages would be based on applicable law (i.e., the priority system). This distribution is modeled in the Representative Preferred Alternative for years 2029 and beyond. Both distribution methods are documented and analyzed in **Appendix C**, Shortage Allocation Model, and **Chapter 3**. Regarding maximum shortage volume, modeling assumptions provide for reductions above the 1.25 maf maximum if needed to avoid critically low elevations at Lake Mead.

<table>
<tr><td>No Action Alternative</td><td colspan="5">The No Action Alternative is included as a requirement of NEPA. Operations would revert to annual determinations announced through the Annual Operating Plan. Pursuant to the LROC, the objective is to maintain a minimum release of water from Lake Powell of 8.23 maf, therefore Lake Powell releases are assumed to be 8.23 maf[1] unless a higher release is required for equalization or a lower release occurs due to Glen Canyon Dam infrastructure limitations.[2] Shortages to the Lower Basin would be based on priority and reach a maximum of 600.0 thousand acre-feet (kaf). This would not represent a continuation of current operations but is generally based on the operating guidance that was in place before the adoption of the 2007 Interim Guidelines. While the authority to use CRSP Upper Initial Units to respond to exigent and emergency conditions was recognized at that time, no specific framework for such activities had been developed, so no defined activities are included in this alternative. Existing Intentionally Created Surplus (ICS) would be delivered in accordance with existing agreements, but there would be no new storage and delivery mechanisms.</td></tr>
<tr><td></td><td>Shortage Guidelines to Reduce Deliveries from Lake Mead[3]</td><td>Coordinated Reservoir Operations (Lake Powell and Lake Mead)</td><td>Storage and Delivery of Conserved System and Non-system Water[3]</td><td>Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]</td><td>Additional Activities Above Lake Powell</td></tr>
<tr><td></td><td>• Shortages determined based on Lake Mead elevation
• Shortage volume of 400.0, 500.0, and 600.0 kaf at elevations 1,075, 1,050, and 1,025 feet, respectively
• Shortages distributed based on priority</td><td>• Lake Powell release of 8.23 maf unless more is required for equalization releases
• Releases less than 8.23 maf below elevation 3,490 feet due to Glen Canyon Dam infrastructure limitations</td><td>• No new storage and delivery mechanism to replace ICS
• Delivery of existing ICS in accordance with existing agreements</td><td>• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions</td><td>• No specific additional activities above Lake Powell defined</td></tr>
</table>

[1] Article II(2) of the LROC states the "objective shall be to maintain a minimum release of water from Lake Powell of 8.23 [maf]." Reclamation recognizes that entities in the Basin have different legal positions regarding how this LROC statement incorporates other Law of the River elements to determine annual releases. Reclamation also recognizes that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted.

[2] Releases from Glen Canyon Dam may be unable to achieve the specified annual release volume when Lake Powell is below elevation 3,490 feet due to infrastructure constraints. Modeling assumptions for all alternatives reflect this constraint (see **Appendix A**).

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

<table>
<tr><td>Basic Coordination Alternative</td><td colspan="5">This alternative is designed to be implementable absent new agreements among Basin water users. Lake Powell releases would primarily be 8.23 maf, with some releases above and below 8.23 maf, and minimum releases of 7.0 maf. Lake Powell elevations could be increased by releases from CRSP Upper Initial Units within their respective RODs to protect infrastructure at Glen Canyon Dam. Reclamation would identify triggers for when additional Upper Basin actions are needed to protect critical infrastructure. Lower Basin shortages up to 1.48 maf would be triggered based on Lake Mead elevation and distributed consistent with priority system. Existing ICS would be delivered in accordance with existing agreements, but there would be no new delivery and storage mechanisms.</td></tr>
<tr><td></td><td>Shortage Guidelines to Reduce Deliveries from Lake Mead[3]</td><td>Coordinated Reservoir Operations (Lake Powell and Lake Mead)</td><td>Storage and Delivery of Conserved System and Non-system Water[3]</td><td>Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]</td><td>Additional Activities Above Lake Powell</td></tr>
<tr><td></td><td>• Shortages based on Lake Mead elevation up to 1.48 maf
• Shortages distributed based on priority
• Identify conditions when additional reductions may be needed to avoid reaching critically low elevations</td><td>• Lake Powell releases are determined based on Lake Powell elevation unless equalization releases are required
• Releases range from 7.0 to 9.5 maf, unless more is required for equalization releases
• Identify conditions when additional action may be needed for infrastructure protection</td><td>• No new storage and delivery mechanism to replace ICS
• Delivery of existing ICS in accordance with existing agreements</td><td>• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions</td><td>• Releases from CRSP Upper Initial Units within their respective RODs and contingent on hydrologic conditions to protect infrastructure at Glen Canyon Dam
• Identify conditions when additional Upper Basin actions may be needed for infrastructure protection</td></tr>
</table>

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Enhanced Coordination Alternative

This alternative is based on concepts from Basin Tribes, federal agencies, and other stakeholders to achieve protection of critical infrastructure while benefitting key resources (e.g., natural, hydropower and recreation) through an approach to distributing storage between Lake Powell and Lake Mead. Lake Powell releases would be determined based on a combination of Lake Powell and Lake Mead elevations, 10-year running-average hydrology, and Lower Basin deliveries. This alternative would include storage and delivery mechanisms for Lake Powell and Lake Mead and extensive flexibilities for all users. The operations incorporate Basin-wide shared contributions to the system, including Upper Basin conservation that would be stored in Lake Powell and Lower Basin shortages starting at 1.3 maf, approximately the average annual evaporative and system losses at and below Lake Mead, and reaching a maximum of 3.0 maf. Shortages would be triggered based on combined storage in Lake Powell and Lake Mead and distributed pro rata.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)**	**Storage and Delivery of Conserved System and Non-system Water[3]**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
• Shortages determined based on combined storage in Lake Powell and Lake Mead • Shortages begin at 60% full at a volume of 1.3 maf, then increase linearly, reaching a maximum of 3.0 maf at 30% full and below • Shortages distributed pro rata	• Lake Powell releases determined based on a combination of Lake Powell and Lake Mead elevations, 10-year running-average hydrology, and Lower Basin deliveries • Releases range from 4.7 to 10.8 maf	• Storage up to 5.0 maf in Lake Mead with additional 2.0 maf Protection Pool; included for purposes of determining Lake Powell releases and shortages • Storage up to 2.0 maf in Lake Powell; included for purposes of determining Lake Powell releases but excluded from shortage determinations • Existing ICS converted to new mechanism immediately • Extensive flexibilities for all users: intra- and interstate transactions within each basin • Tribal water (both conserved consumptive use and unused) including in Lake Powell conservation pool and Lake Mead Protection Pool	• Surplus determinations limited to 70R (spill avoidance strategy) and Flood Control conditions	• Upper Basin conservation contributed to the Lake Powell conservation pool based on hydrologic conditions: up to 200.0 kaf per year for first 5 years, up to 275.0 kaf per year for second 5 years, up to 350.0 kaf starting in year 11

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Maximum Operational Flexibility Alternative

This alternative is informed by a proposal submitted by a consortium of conservation organizations and incorporates proactive responses, targeted reservoir management strategies, and innovative and flexible tools to address an increasingly variable set of future hydrologic conditions. Lake Powell releases would range from 5.0 to 11.0 maf and would be determined by total CRSP system storage and recent hydrology. Releases would switch to "run-of-river" when Lake Powell is at 3,510 feet or lower. The operations incorporate Basin-wide shared contributions, including up to 4.0 maf of shortages in the Lower Basin triggered by combined seven-reservoir storage (CRSP Upper Initial Units, Lake Mead, Lake Mohave, and Lake Havasu) and recent hydrology and voluntary water contributions from both basins.

Shortage Guidelines to Reduce Deliveries from Lake Mead[3]	**Coordinated Reservoir Operations (Lake Powell and Lake Mead)[3]**	**Storage and Delivery of Conserved System and Non-system Water**	**Surplus Guidelines to Increase Deliveries/ Releases from Lake Mead[3]**	**Additional Activities Above Lake Powell**
• Shortages determined based on combined seven-reservoir storage and recent hydrology • Shortages start at 80% full and increase linearly, subject to upward adjustment based on hydrology, reaching a maximum of 4.0 maf • Shortages distributed based on priority, as described in Approach 1 of the Supply Driven Alternative	• Lake Powell releases determined based on total Upper Basin system storage and recent hydrology • Releases subject to downward adjustment based on hydrology and range from 5.0 to 11.0 maf • Releases switch to "run-of-river" when Lake Powell is at elevation 3,510 feet or lower	• Storage up to 8.0 maf in either Lake Powell or Lake Mead; excluded for purposes of determining Lake Powell releases and shortages • Existing ICS converted to new mechanism over 5 years • Extensive flexibilities for all users: transactions within and across basins, including interstate and inter-basin	• Surplus determinations limited to Flood Control conditions	• Average of 200.0 kaf of Upper Basin annual conservation based on hydrologic conditions contributed to the Lake Powell conservation pool

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

<table>
<tr><td>Supply Driven Alternative</td><td colspan="5">Annual Lake Powell releases are determined based on a 65 percent of 3-year-average natural flow at Lees Ferry. Lake Powell elevations could be increased by releases from CRSP Upper Initial Units within their respective RODs to protect infrastructure at Glen Canyon Dam. This alternative would include new delivery and storage mechanisms for Lake Powell and Lake Mead. Lower Basin shortages up to 2.1 maf would be triggered based on Lake Mead elevation. This alternative analyzes two approaches to shortage distribution: state-based combined with Lower Basin-wide priority and state-based combined with Lower Basin-wide pro rata.</td></tr>
<tr><td></td><td>Shortage Guidelines to Reduce Deliveries from Lake Mead[3]</td><td>Coordinated Reservoir Operations (Lake Powell and Lake Mead)</td><td>Storage and Delivery of Conserved System and Non-system Water[3]</td><td>Surplus Guidelines to Increase Deliveries/Releases from Lake Mead[3]</td><td>Additional Activities Above Lake Powell</td></tr>
<tr><td></td><td>• Shortages determined based on Lake Mead elevation
• Shortages start at 1,145 feet and reach a maximum of 2.1 maf at 1,000 feet and below
• Shortages distributed using two approaches: LB Priority and LB Pro Rata</td><td>• Lake Powell releases determined primarily based on 65% of 3-year natural flows at Lees Ferry
• Releases range from 4.7 to 12.0 maf</td><td>• Storage up to 8.0 maf in Lake Mead; excluded for purposes of determining shortages
• Storage up to 3.0 maf at Lake Powell; included for purposes of determining Lake Powell releases
• Existing ICS converted to new mechanism over 10 years
• Expanded flexibilities: interstate exchanges within each basin</td><td>• Surplus determinations based on Lake Mead elevation at or above 1,165 feet, 70R (spill avoidance strategy) or Flood Control conditions</td><td>• Increased releases from CRSP Upper Initial Units by up to 500.0 kaf per year within their respective RODs and contingent on hydrologic conditions to protect infrastructure at Glen Canyon Dam
• Up to 200.0 kaf of Upper Basin annual conservation based on hydrologic conditions contributed to the Lake Powell conservation pool
• In years when Lake Powell cannot meet its required water year release because of low elevation, additional “gap water” is introduced into the system and tracked to be released in subsequent years</td></tr>
</table>

[3] These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico. **Appendix A** provides additional detail. Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

2.6 Summary of Tradeoffs between Alternatives

Operations at Lake Powell and Lake Mead inherently involve tradeoffs among resources that benefit from different fundamental system elements: storage in each reservoir, dam releases, river flows, and water deliveries. For example, it is not possible for a set of operating guidelines to have the most robust performance with respect to maximizing protection of critical elevations, minimizing reductions in water deliveries, and maximizing hydropower generation all at once. With the extended period of dry hydrologic conditions since 2000 and the resulting depletion of storage, these tradeoffs have become more stark, and achieving a broadly acceptable balance between resources is now more difficult than ever before.

Based on the analysis in this Final EIS and the key tradeoffs shown below, the Preferred Alternative, as analyzed in the Representative Preferred Alternative, appropriately balances the inherent system tradeoffs: it is a practical approach to robust protection of critical infrastructure while considering adverse impacts to water users and avoiding unnecessary impacts to other resources.

2.6.1 Tradeoffs Analysis

While there are many important metrics across Basin resources, it is instructive to summarize the high-level system impacts through five metrics related to Lake Powell and Lake Mead elevations, Lower Basin deliveries, and releases from Glen Canyon Dam. Analyzing tradeoffs among the metrics described in **Table 2-6** also provides important insight into the tradeoffs among other resources.

Table 2-6
High Level Performance Metrics Included in Figure 2-3

Metric Name	Description
Percent of months in which Lake Powell stays above elevation 3,500 feet	Elevation 3,500 feet provides a buffer above 3,490 feet, below which the reliability of infrastructure to meet critical downstream water supply needs may be critically impacted and hydropower cannot be produced at Glen Canyon Dam
Percent of months in which Lake Mead stays above elevation 975 feet	Elevation 975 feet provides a buffer above 950 feet, below which infrastructure may be critically impacted and hydropower cannot be produced at Hoover Dam
Percent of years in which Lake Mead dead pool-related reductions[13] are avoided	Delivery reductions due to Lake Mead being near dead pool (elevation 895 feet) resulting in large magnitudes of reductions to Lower Basin water users
Average annual shortage	The average annual shortage that occurs under each alternative provides important summary information for Lower Basin water users and context for reservoir-based performance

[13] Dead pool and Hoover Dam infrastructure can start to impact Lake Mead's ability to make deliveries to the Lower Basin at elevation 950 feet. Restrictions on water deliveries would occur when Lake Mead is near dead pool, resulting in large reductions (referred to as "dead pool-related reductions"). Although not considered an operational element of the alternatives, accounting for such reductions is an important performance metric.

Metric Name	Description
Average water year releases from Glen Canyon Dam	The average water year release from Glen Canyon Dam that occurs under each alternative provides important context for reservoir-based performance

The elevations described in **Table 2-6** have operational relevance, and comparing alternative performance relative to these elevations provides meaningful insight. In practice, operational implementation would include identifying elevations above critical thresholds (i.e., 3,490 feet and 950 feet) at which additional responsive actions could be taken in advance to avoid reaching those critical elevations. The "buffer" elevations shown in **Table 2-6** (i.e., 3,500 feet and 975 feet) may or may not represent correspond to operational decision for actual implementation; here, they are used for analytical purposes in this Final EIS.

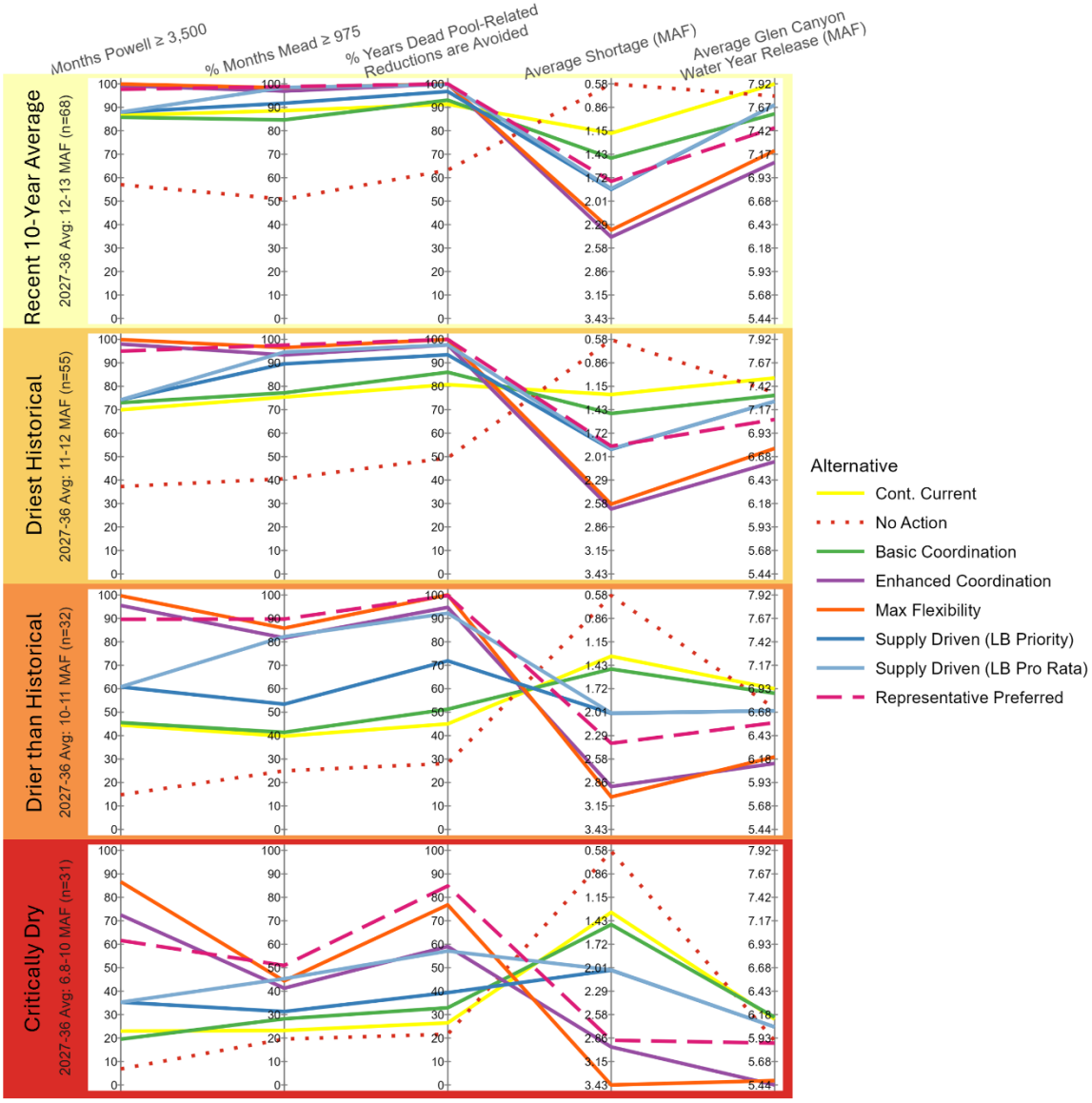
Figure 2-3 summarizes how the alternatives and the Continued Current Strategies Comparative Baseline[14] (labeled "Cont. Current") perform over the next 10 years in five vertical axes that correspond to the five key metrics described in **Table 2-6**. The performance of each alternative is captured by a colored, segmented line that crosses the axes at different vertical positions, where the height denotes performance. Crossing lines are a visual cue that there is a tradeoff between different performance metrics. The five-metric performance summary is divided into four categories of potential 2027-2036 future hydrologic conditions that get increasingly dry from top to bottom.[15] The hydrologic categories are summarized in **Table 2-7**. Results are divided into these categories to demonstrate how the alternatives respond under different assumptions about future hydrologic conditions and to explore the impacts of hydrology on performance tradeoffs.

A key performance tradeoff demonstrated by **Figure 2-3** is the tradeoff between percent of time in which critical reservoir elevations and dead pool-related reductions are avoided (first three axes from left) and average shortage (fourth axis from left). In the Recent 10-Year Average hydrologic category, this stands out as a difference between the No Action Alternative and the action alternatives, but in the drier hydrologic categories (especially Drier than Historical and Critically Dry), the performance differences between the action alternatives becomes clearer and the tradeoffs (indicated by the crossing lines) become steeper: the Maximum Operational Flexibility and Enhanced Coordination Alternatives incorporate large shortages and better protect the reservoirs; the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Basic Coordination Alternative have lower volumes of shortage and lower reservoir protection; and the No Action Alternative provides minimal protection and results in a high frequency of dead pool-related reductions while imposing minimal shortage. Across hydrologic categories, the Representative Preferred Alternative balances tradeoffs differently than other action alternatives. This is evident beginning in the Driest Historical hydrologic category, where it provides protection of Lake Powell and Lake Mead elevations similar to the most protective alternatives, while the average shortage volumes are similar to the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches).

[14] This scenario represents no changes from current operations and relies on strategies and agreements that expire in 2026. It is provided as a comparative baseline to inform an understanding of how the alternatives perform relative to current operations.

[15] Wetter futures were also tested and are included in the impact analysis; however, for this analysis the hydrologic categories shown are most informative.

Figure 2-3
Key Performance Tradeoffs in Different Hydrologic Conditions



Note: Differences in Lake Mead performance between Supply Driven (Lower Basin [LB] Priority approach) and the Supply Driven (LB Pro Rata approach) Alternatives reflect how different shortage distributions interact with assumptions regarding the use of the storage and delivery mechanism for conserved water.

Table 2-7
Hydrologic Categories Included in Figure 2-3

Hydrologic Category	Average Annual Simulated Lees Ferry Flow, 2027-2036 (maf)	Description
Recent 10-Year Average	12-13	Hydrologic conditions in this category are similar to the historical average from 2016-2025 (12.1 maf)[16]
Driest Historical	11-12	Hydrologic conditions in this category are similar to the driest 10-year period in the historical record (11.8 maf, 2012-2021)
Drier than Historical	10-11	Hydrologic conditions in this category are 7-15% (0.8 to 1.8 maf) drier than the driest 10-year period in the historical record
Critically Dry	<10	Hydrologic conditions in this category are 15-42% (1.8-5.0 maf) drier than the driest 10-year period in the historical record

In Drier than Historical hydrologic futures, the Maximum Operational Flexibility and Enhanced Coordination Alternatives show that lower WY releases from Glen Canyon Dam provide more protection to keep Lake Powell above 3,500 feet, while the higher water year releases in the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives result in significantly higher frequencies of Lake Powell falling below 3,500 feet. The Representative Preferred Alternative falls in between the Supply Driven (both LB Priority and LB Pro Rata approaches) and Enhanced Coordination Alternatives: it releases less from Glen Canyon on average than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and better protects elevation 3,500 feet, but it releases more and offers less protection compared to the Enhanced Coordination Alternative. In the Critically Dry hydrologic category, water year releases are low across all alternatives, but only the Representative Preferred (62 percent of months), Enhanced Coordination (72 percent of months) and Maximum Operational Flexibility (87 percent of months) Alternatives protect 3,500 feet more than half of the time. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and Basic Coordination Alternative maintain elevations above 3,500 feet in 35 percent and 20 percent of months, respectively.

The effectiveness of large shortages at preventing dead pool-related delivery reductions is clearest in the Critically Dry hydrologic category, where the Representative Preferred, Maximum Operational Flexibility, and Enhanced Coordination Alternatives rely on large average shortages to significantly outperform the other alternatives in avoiding dead pool-related reductions. However, in Critically Dry conditions, even these more protective alternatives result in Lake Mead elevations below 975 feet in 49, 56, and 59 percent of months, respectively.

Figure 2-3 is a quantitative representation of system tradeoffs and shows how those tradeoffs are exacerbated by drying hydrologic conditions. The analysis in this figure demonstrates how the sideboards of the Preferred Alternative, as analyzed in the Representative Preferred Alternative,

[16] The 10-year average for 2014-2023 (12.8 maf), 2015-2024 (12.6 maf), and 2016-2025 (12.1 maf) are all between 12.0 and 13.0 maf.

appropriately balance the tradeoffs across key system metrics and provide protection in conditions drier than the ongoing, unprecedented drought. The Representative Preferred Alternative achieves good performance across key system metrics related to critical infrastructure in the driest hydrologic conditions the Basin has experienced (Driest Observed Hydrology) but imposes lower average shortages and enables higher Glen Canyon Dam releases than other similarly protective alternatives. In conditions that are slightly drier than observed history (Drier than Historical Hydrology), the Representative Preferred Alternative maintains this moderate balance of performance between reservoir elevations, shortages, and Glen Canyon Dam releases. In the driest hydrologic conditions modeled (Critically Dry Hydrology), the ability of any set of operations to achieve good performance in these metrics is significantly diminished, but the Representative Preferred Alternative shows that the Preferred Alternative sideboards can protect critical infrastructure in the majority of these conditions while considering adverse impacts to Lower Basin water users.

2.6.2 Conclusions

This Final EIS analyzes a reasonable and broad range of alternatives for the operational elements identified in the proposed federal action. These alternatives were developed through extensive engagement with a wide range of partners and stakeholders as well as the public during a timeframe of over 4 years. In the absence of a consensus long-term agreement, Reclamation has included a Preferred Alternative decision framework in this Final EIS that establishes the operational principles, sideboards, and process that would govern development and adoption of operating guidelines through 2036.

The sideboards of the Preferred Alternative were analyzed through the Representative Preferred Alternative, and the analysis of the potential impacts of these sideboards provides environmental compliance for decisions made consistent with the decision framework. Based on the analysis in this Final EIS and the key tradeoffs shown above, the Preferred Alternative, as analyzed in the Representative Preferred Alternative, appropriately balances the inherent system tradeoffs: it is a practical approach to robust protection of critical infrastructure while considering adverse impacts to water users and avoiding unnecessary impacts to other resources.

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Chapter 3. Affected Environment and Environmental Consequences

3.1 Introduction

This chapter describes the existing conditions of the environmental resources (e.g., hydrologic, biologic, and socioeconomic) of the Basin, followed by an analysis of the extent and magnitude of potential effects on each resource from the alternatives described in **Chapter 2**. Only resources that could potentially be significantly affected by the alternatives are analyzed. Resources considered for analysis but determined not to be significantly affected include the following:

- **Transportation** – No impacts on transportation are anticipated in the analysis area, as the proposed changes are operational in nature. Impacts to the Lake Powell ferry are analyzed in the recreation section.
- **Minerals** – No impacts on minerals or mineral rights are anticipated because all proposed Lake Powell and Lake Mead operational changes and their associated releases and elevations would not affect minerals or mineral rights.
- **Noise** – No impacts on noise are anticipated in the analysis area, as existing noise conditions are expected to continue at the same level under all proposed Lake Powell and Lake Mead operational changes.
- **Light** – No impacts on light are anticipated in the analysis area, as existing light conditions are expected to remain unchanged under all proposed Lake Powell and Lake Mead operational changes.

Section 3.2, Analysis Methods, describes the approach used for assessing the environmental consequences, including the geographic and temporal scope, alternatives and a comparative baseline, and modeling. This is followed by the individual resource sections, which represent a summarized overview of the affected environment and environmental consequences. Further information for each resource section can be found in the corresponding technical appendices identified in each section.

3.2 Analysis Methods

3.2.1 Geographic Scope

Consistent with the geographic scope analyzed in the 2007 Interim Guidelines Final EIS, the geographic scope that would be affected by the proposed federal action begins at full pool of Lake Powell and extends downstream along the mainstream Colorado River floodplain to the SIB with Mexico. This proposed federal action would also potentially affect interests of water users in the Lower Division States in service areas that extend beyond the Colorado River floodplain. Additionally,

numerous tribes hold Colorado River water entitlements and could be affected by water supply availability.

Although the proposed federal action is focused on Lake Powell and Lake Mead operations, management strategies that include activities upstream of Lake Powell are being analyzed in this Final EIS. These activities include Upper Basin conservation and, if warranted to protect critical reservoir elevations, operations at the CRSP Upper Initial Units (see **Map 1-1**). Operations at the CRSP Upper Initial Units specifically contemplated in the Final EIS alternatives are intended to remain within the scope of the existing Records of Decision (Reclamation 2006a, 2006b, 2012).[1] [2] Accordingly, the Final EIS does not expand the geographic scope of analysis upstream of Lake Powell. With respect to Upper Basin conservation, the nexus to the proposed federal action is the storage and delivery of that conserved water in Lake Powell. The effects of this storage in and delivery from Lake Powell are within the scope of the EIS (see **Section 3.3**, Hydrologic Resources, and **TA 3**, Hydrologic Resources), while specific activities that may be undertaken in the Upper Basin to generate the conserved water are not within the scope of this EIS. Any such activities are unknown at this time and will not necessarily require federal decision making. Any federal decisions associated with these conservation activities will be assessed outside of this EIS.

For ease of discussion with respect to the geographic scope of this Final EIS and the affected areas and potential effects, the Colorado River has been divided into nine reaches, as shown on **Table 3-1** and **Map 3-1**. The geographic scope described in this section is a standard area of analysis; for some resource topics, the impact analysis area differs from this scope to account for the impacts on that specific resource. When different, the impact analysis area is defined in the resource's specific methodology section.

3.2.2 Temporal Scope

For purposes of analysis, the temporal scope of this EIS extends from 2027 through 2060, providing a framework for assessing short-term to long-term effects.

3.2.3 Alternatives Analyzed and Comparative Baseline

The analysis for each resource section focuses on specific issues identified during internal and public scoping (Reclamation 2023b). Impact analysis is provided for the Preferred Alternative, as represented by the Representative Alternative, described in **Chapter 2**, and all the "action alternatives" described in **Appendix S,** Additional Description of Alternatives (Basic Coordination Alternative, Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, and Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]), along with the No Action Alternative. A No Action Alternative typically serves as an extension of current operations to provide a benchmark to

[1] RODs for CRSP Upper Initial Units include those for Flaming Gorge, Blue Mesa (a component of the Aspinall Unit), and Navajo reservoirs.

[2] While the Secretary will consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the CRSP Upper Initial Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes as stated in the 1956 Colorado River Storage Project Act. See additional information regarding the modeling assumptions of the CRSP Upper Initial Units in **Appendix A,** CRSS Modeling Documentation **Section A.5.11**.


Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023, BLM GIS 2025, US Census GIS 2024; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: June 30, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.
BUREAU OF RECLAMATION
Map 3-1 Colorado River Reaches and Geographic Scope
Gypsum Canyon to Glen Canyon Dam
Glen Canyon Dam to Separation Canyon
Separation Canyon to Hoover Dam
Hoover Dam to Davis Dam
Davis Dam to Parker Dam
Parker Dam to Cibola Gage
Cibola Gage to Imperial Dam
Imperial Dam to Northerly International Boundary (NIB)
NIB to Southerly International Boundary (SIB)
Geographic scope
Major dam or river reach boundary
Colorado River Basin, Upper and Lower Basins
Colorado River above and below the geographic scope of analysis
Major Colorado River tributary
States in the Colorado River Basin
WYOMING
NEVADA
UTAH
COLORADO
CALIFORNIA
ARIZONA
NEW MEXICO
USA
MEXICO
Lake Powell Full Pool
Glen Canyon Dam
Lake Powell
Lake Mead
Hoover Dam
Separation Canyon
Davis Dam
Parker Dam
Cibola Gage
Imperial Dam
NIB
SIB
Salton Sea
Upper Basin
Lower Basin
Yampa River
White River
Duchesne River
Green River
San Rafael River
Gunnison River
Dolores River
San Juan River
Virgin River
Muddy River
Verde River
Little Colorado River
Salt River
Gila River
0
100
Miles

Table 3-1
Colorado River Reaches and Reach Limits in the Geographic Scope

Reach	Reach Limits
Lake Powell and Glen Canyon Dam	Lake Powell at full pool to Glen Canyon Dam (RM -15.8)
Glen Canyon Dam to Lake Mead	Glen Canyon Dam (RM -15.8) to Separation Canyon (RM 240), including GCNP
Lake Mead and Hoover Dam[1]	Separation Canyon (RM 240) to Hoover Dam, including Lake Mead
Hoover Dam to Davis Dam	Hoover Dam (RM 342.2) to Davis Dam (RM 276), including Lake Mohave
Davis Dam to Parker Dam	Davis Dam (RM 276) to Parker Dam (RM 192.3), including Lake Havasu
Parker Dam to Cibola Gage (Adobe Ruin)	Parker Dam (RM 192.3) to Adobe Ruins and Reclamation's Cibola Gage near the terminus of Cibola Lake (RM 87.3)
Cibola Gage to Imperial Dam	Reclamation's Cibola Gage near the terminus of Cibola Lake (RM 87.3) to Imperial Dam (RM 49.2)
Imperial Dam to Northerly International Boundary (NIB)	Imperial Dam (RM 49.2) to the NIB (RM 23.1)
Northerly International Boundary (NIB) to Southerly International Boundary (SIB)	NIB (RM 23.1) to SIB (RM 0.0)

[1] For purposes of this EIS, RMs are measured differently along the length of the Colorado River in the Upper and Lower Basins. RMs in the Upper Basin begin at Glen Canyon Dam and increase from north to south. The Lower Basin RMs increase upstream (south to north), beginning at RM 0.0 at the SIB with Mexico and increasing to RM 342.2 at Hoover Dam. This system of identifying RMs is consistent with common practices within each Basin. Dam locations, reach limits, and other features are identified at their respective RM.

compare the extent and magnitude of the impacts from each action alternative. However, as described in **Chapter 2**, the expiration of current domestic and international implementing agreements means that the No Action Alternative represents a change in operations. As a result, the No Action Alternative does not serve as an appropriate baseline to compare impacts. Therefore, a CCS Comparative Baseline scenario is provided to assess the impacts if operations were to continue under the current direction and strategies.[3] While the CCS Comparative Baseline is not an action alternative, it is a contemporary set of operations that stakeholders are familiar with that can be used to comparatively evaluate the performance of the alternatives (including the No Action Alternative).

As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative

[3] This framework relies on strategies and agreements that expire in 2026, including the 2007 Interim Guidelines (as amended), the 2019 DCP, Minute 323 of the 1944 Water Treaty, and other agreements.

Preferred Alternative which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval.

The key modeling assumptions for the CCS Comparative Baseline are summarized in **Table 3-2** and additional details are included in **Appendix A**, CRSS Model Documentation. These modeling assumptions were designed to reflect a continuation of the primary existing agreements for Colorado River management including the 2007 Interim Guidelines, the 2019 DCP, and Minute 323 of the 1944 Water Treaty.

3.2.4 Hydrologic Modeling

Hydrologic modeling of the Colorado River system was conducted to determine the potential hydrologic effects of the alternatives considered in this Final EIS. The hydrologic modeling provides projections of potential future Colorado River system conditions (such as reservoir elevations, reservoir releases, and river flows) under the No Action Alternative (and the CCS Comparative Baseline) for comparison with conditions simulated for the action alternatives. Due to uncertainties associated with future inflows, which are the largest driver of system outcomes under any given operation, hundreds of simulations were performed for each alternative to explore how each responds to a range of plausible future conditions. The simulations and analysis framework were designed to avoid reliance on narrow hydrologic assumptions, ensure meaningful comparison between alternatives, and provide reliable information about how the system would respond under each alternative. Hydrologic modeling is the driver for various resource impacts and is therefore the basis for analyzing potential effects on other environmental resources (e.g., recreation, biological resources, and energy). The potential effects on specific resource issues are identified for each alternative and compared with those under the No Action Alternative and CCS Comparative Baseline.

Hydrologic Model Description

Future Colorado River system conditions under the No Action Alternative, CCS Comparative Baseline, and the action alternatives were simulated using CRSS. CRSS, implemented through RiverWare™, is the core simulation tool, providing monthly and annual outputs of key variables, including reservoir storage, reservoir elevations, dam releases, and river flows. The simulation is based on a mass-balance calculation that accounts for water entering the system, water uses (diversions and consumptive use), water losses (evaporation), intervening gains and losses, and water movement through the system.

Input data for the model include monthly natural inflows, physical process parameters (e.g., evaporation rates for reservoirs), initial reservoir conditions, and future diversion and depletion schedules for the Basin States and for Mexico. The operating rules for the Colorado River system reservoirs (including Lake Powell and Lake Mead) are also considered inputs to the model. Detailed descriptions of CRSS and the hydrologic model process are included in **Appendix A**, CRSS Model Documentation.

Table 3-2
Summary of the CCS Comparative Baseline

Shortage Guidelines to Reduce Deliveries from Lake Mead[1]	Coordinated Reservoir Operations (Lake Powell and Lake Mead)	Storage and Delivery of Conserved System and Non-system Water (Lake Mead and/or Lake Powell)[1]	Surplus Guidelines to Increase Deliveries/Releases from Lake Mead[1]	Additional Activities Above Lake Powell
• Shortages determined based on Lake Mead elevation • Shortage volume of 400, 500, and 600 kaf at elevations 1,075, 1,050, and 1,025 feet, respectively • DCP and BWSCP contributions ranging from 241 kaf at elevation 1,090 feet to 750 kaf at elevation 1,025 feet • Shortages and DCP contributions distributed based on existing agreements	• Lake Powell releases are determined based on Lake Powell and Lake Mead elevations • 3 tiers of releases ranging from 9.5 to 7.0 maf with potential adjustments down to 6.0 maf for infrastructure protection • Equalization tier with higher releases possible at higher Lake Powell elevations	• Storage up to 4.2 maf in Lake Mead • Delivery of existing ICS assumed to continue through the analysis period (2027-2060) in accordance with existing agreements designed to reflect the historical range of use of the ICS mechanism • Creation of ICS assumed to continue through the analysis period (2027-2060) in accordance with existing agreements designed to reflect the historical range of use of the ICS mechanism	• Surplus determinations based on Lake Mead Elevation at or above 1,145 feet: Domestic Surplus, 70R (spill avoidance strategy), Flood Control Conditions, and increases in deliveries to Mexico per Minute 323	• Releases from CRSP Upper Initial Units within their respective RODs and contingent on hydrologic conditions to protect infrastructure at Glen Canyon Dam

[1]These operational elements contain modeling assumptions for water deliveries to Mexico. Shortage volumes include assumptions related to reductions in water deliveries to Mexico based on Minute 323. Lake Mead storage volumes for the Storage and Delivery of Conserved System and Non-system Water include assumptions related to storage available to Mexico. Surplus Guidelines include assumptions related to increased deliveries to Mexico based on Minute 323. **Appendix A** provides additional detail. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Assumptions

In addition to the specific operating rules necessary to model each alternative (discussed in **Chapter 2** and the associated appendices) and the CCS Comparative Baseline, modeling of Colorado River system operations requires assumptions about various aspects of inflows, water delivery, and system operations that are common to all alternatives and the CCS Comparative Baseline. These assumptions include:

- **Input Data Consistency:** All simulations use a common set of input data to isolate the effects of alternative operational guidelines.
- **Hydrologic Variability:** Simulations use 400 different hydrologic traces to capture the variability inherent in natural flows.
- **Initial Conditions:** In the Draft EIS, three sets of 2027 reservoir elevations were used to capture hydrologic uncertainty between 2025 and 2027. Since the Draft EIS was developed, the observed hydrology supports using the Low initial conditions only because they are similar to the likely starting point at the end of 2026.
- **Future Water Demands:** Upper Basin depletion schedules were developed from the Upper Colorado River Commission's updated 2016 Depletion Demand Schedule (**Appendix L**, Upper Division Depletion Schedules). The modeled Upper Basin use varies due to hydrologic conditions and alternative specific conservation assumptions. Lower Basin depletion schedules were developed by Reclamation (**Appendix M**, Lower Division Depletion Schedules). Lower Basin depletion schedules start at full apportionment and modeled use varies by alternative specific shortage, surplus, and conservation assumptions.
- **Physical Process Parameters:** Assumptions regarding evaporation, bank storage, and other processes are based on the most current measurements and modeling studies.
- **Infrastructure Constraints:** Modeled limitations on operations at high and very low reservoir elevations.

Detailed modeling assumptions and other aspects of the simulation are documented in **Appendix A**, CRSS Model Documentation. All results in **Chapter 3**, and the supporting technical appendices in **Volume III** are based on the single Upper Basin demand assumptions described above. **Appendix I**, Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead, presents a sensitivity analysis that evaluates how future Upper Basin demands assumptions influence modeled system conditions and vulnerabilities for select hydrologic and water delivery impact indicators.

3.2.5 Resource Model Description

In addition to CRSS, a suite of resource-specific models was used to evaluate potential effects of the alternatives on individual resource areas. These models build on CRSS outputs and provide finer-scale or specialized analyses tailored to individual resource areas. **Table 3-3** lists the primary models and the resources they support.

Table 3-3
Models and Supported Resources

Model/Owner	Primary Purpose	Resource Areas Supported
CRSS/RiverWare™ (Reclamation)	Core system operations model; simulates reservoir elevations, releases, river flows, and salinity.	Hydrologic Resources; Water Deliveries; Dams and Electrical Resources, Water Quality; Visual Resources; Vegetation; Terrestrial Wildlife; Geomorphology and Sediment; Air Quality; Fish and other Aquatic Species; Tribal; Recreation; Population and Land Use; Indian Trus Assets
SAM / Alternative Distribution Model(s) (ADM) (Reclamation)	Emulates a distribution of Colorado River water shortage among entitlement holders under shortage tiers and allocation assumptions; translates tiers into volumes for specific users/jurisdictions.	Water Deliveries; Socioeconomics; Indian Trust Assets (ITAs); Lands and Population
High-Flow Experiment (HFE) / Sediment models (Grand Canyon Monitoring and Research Center [GCMRC] / U.S. Geological Survey [USGS])	Simulates sediment transport and geomorphic response to HFEs (sand mobilization, sandbar building, channel budgets). Evaluates whether and how often HFEs rebuild sandbars.	Geomorphology and Sediment
CRSP Python model (CRiSPPy)/WAPA	An advanced hydropower scheduling tool that projects annual electricity production and powerplant firm capacity. The hourly release data generated by this model is used as an input for many of the GCMRC models listed below.	Dams and Electrical Power Resources
GCMRC Dissolved Oxygen and Temperature Models for Glen Canyon, Lees Ferry and Grand Canyon (Reclamation/ GCMRC/USGS)	Evaluates thermal stratification, interflows, and downstream release water temperatures and dissolved oxygen conditions, especially important for aquatic resource (humpback chub, trout) impacts and selective withdrawal scenarios.	Water Quality; Fish and Aquatic

Model/Owner	Primary Purpose	Resource Areas Supported
Glen Canyon National Recreation Area (NRA) Exposed Shoreline Model (Lake Powell) (subaerially exposed sand model) (USGS/GCMRC/ Southwest Biological Science Center)	Predicts exposed sand and shoreline area as reservoir levels change; used to estimate aeolian sand availability and cultural/paleo exposure.	Air Quality; Cultural Resources; Paleontological Resources
Lake Mead Dust Model (USGS/GCMRC)	Predicts potential dust emissions from newly exposed shoreline and estimates human-health/air-quality impacts under drawdown scenarios.	Air Quality
Preservation Risk Model (USGS/GCMRC)	Ranks Lake Powell and Lake Mead (1–5) based on the potential for cultural and paleontological resource preservation to be affected by reservoir levels. Combines a resource distribution model with a preservation hazard model.	Cultural Resources; Paleontological Resources
Joint Cultural/Paleo Models (Sand Area, Vegetation, and Sandbar Models) (USGS/GCMRC)	Integrates the aeolian sand availability model, vegetation habitat suitability model, and sandbar volume model. Together, these evaluate sand supply, vegetation cover, and sandbar dynamics as key drivers of cultural and paleontological resource preservation in the Grand Canyon.	Cultural Resources; Paleontological Resources
Smallmouth Bass Model (entrainment and population growth proxies) (GCMRC)	Estimates entrainment rates of smallmouth bass through Glen Canyon Dam, thermal suitability downstream, and consequent population establishment/growth (λ proxies).	Fish and Aquatic
Whitewater and Angling Economic Model (USGS/GCMRC)	Estimates changes in recreation value (rafting in Grand Canyon, angling in Glen Canyon) under varying flow and condition scenarios.	Recreation
Socioeconomic IMPLAN (Impact Analysis for Planning) commercial regional input-output model	Assesses community-level socioeconomic outcomes (employment, income, tax base, social vulnerability) from water delivery and recreation/hydropower impacts. Converts changes in agricultural output (or other direct effects) into regional economic impacts.	Socioeconomics

Additional specialty models that add layers of analysis to the above models are introduced in their respective resource sections.

3.2.6 Decision Making under Deep Uncertainty

To help inform the impact analysis, a DMDU approach, drawn from a well-established branch of decision science, was implemented to evaluate how each alternative performs across a wide range of plausible future hydrologic and operational conditions. As described in Smith et al. (2022), this approach is appropriate because of extreme uncertainty in future hydrology, the inability to accurately assess the probability distribution of future inflows, and the desire to avoid overconfidence in probabilistic predictions that will vary depending on model inputs.

The DMDU approach is a non-probabilistic evaluation framework that compares alternatives based on their ability to meet specific performance criteria in many potential future conditions and analyzes how the alternatives respond to specific hydrologic conditions. Importantly, the DMDU approach does not assume the likelihood of any future conditions *before* the quantitative analysis is performed. Instead, it first evaluates a broad range of future conditions and then, *after the analysis is presented*, it provides the opportunity to consider whether specific impacts are reasonably foreseeable based on individual and/or expert judgment. Essentially, since there is no way to confidently state the probabilities of different conditions or outcomes occurring, DMDU focuses on applying knowledge and experience at the end of the analysis to assess whether it is reasonable to plan for the specific conditions that result in negative consequences.

Additional background and technical details about the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach.

Note, certain analysis thresholds, such as historic minimum elevations and minimum average flows, were based on observations through June 2026.

Overview of the DMDU Analysis Framework

The key to successful DMDU-style analysis is structured model inputs that capture a range and variety of conditions related to the key factors that drive the uncertainties in the model outputs. For this EIS process, the most impactful uncertainty is future hydrology. Four hundred hydrology sequences (traces) were selected from a suite of data sources that include observed flows, reconstructions of historical flows based on tree ring analysis, statistical models that combine information about recent trends, historical patterns, projected variability, and projections derived from climate models. The traces capture a wide range of potential future conditions and a variety of streamflow statistics. This ensures that the alternatives are thoroughly tested and enables targeted analysis to understand how each alternative responds to specific hydrologic conditions. In the Draft EIS, three sets of 2027 reservoir elevations (High, Mid and Low initial conditions) were used to capture hydrologic uncertainty between 2025 and 2027. Since the Draft EIS was developed, the observed hydrology supports using the Low initial conditions only since they are similar to the projected conditions at the end of 2026. The Low initial conditions are combined with the 400 different hydrology (streamflow) traces. Each alternative is simulated in all 400 futures using CRSS and subsequent resource-specific models. For more information about the hydrology used in this analysis, refer to **Appendix F**, Approach to Hydrologic Uncertainty, and for more information on the initial reservoir condition used in the analysis, refer to **Appendix G**, CRSS Initial Conditions.

Overview of DMDU Figures and Terminology Included in this Analysis

Throughout the resource analysis there are three standard figures: conditional boxplots, robustness heatmaps, and vulnerability bar plots. Each type of figure explains key information regarding performance. When taken together, the figures provide a full picture of how the alternatives compare and whether significant negative impacts are reasonably foreseeable under each alternative. The following sections introduce these figures and provide annotated examples to assist with understanding the resource analysis.

DMDU enables readers to apply individual judgment about the likelihood of specific impacts: The quantitative analysis underpinning this document tests alternatives in a wide range of conditions to identify relationships between hydrologic conditions and system impacts. The DMDU-oriented figures can be combined with historical hydrologic context and future projections to understand whether impacts of concern are reasonably foreseeable. These connections will be demonstrated as each figure is introduced.

Conditional Boxplots

The conditional boxplot figures show how the alternatives respond to different categories of preceding hydrology and enable a comparison of alternatives in specific hydrologic conditions (e.g., average conditions or dry conditions). To create these figures, all 34 years (2027–2060) from all 400 simulated futures (13,600 data points per alternative) are separated into five categories based on their preceding 3-year average Lees Ferry natural flow.[4,5] Then, the resource outcomes for each year are sorted into their respective categories, resulting in a range of potential system outcomes that could occur given the preceding hydrologic conditions. The range of values is presented as a boxplot to summarize the statistical distribution of outcomes.

The flow categories were defined based on how they compare to historical conditions and stakeholders' understanding of different historical periods, as presented in **Table 3-4**, Colorado River Flow Categories. **Figure 3-1**, Preceding 3-Year Average Lees Ferry Natural Flow, 2000 to 2024, shows how the preceding 3-year average Lees Ferry natural flow varied from 2000 to 2024 and demonstrates the relevance of these categories in recent history.

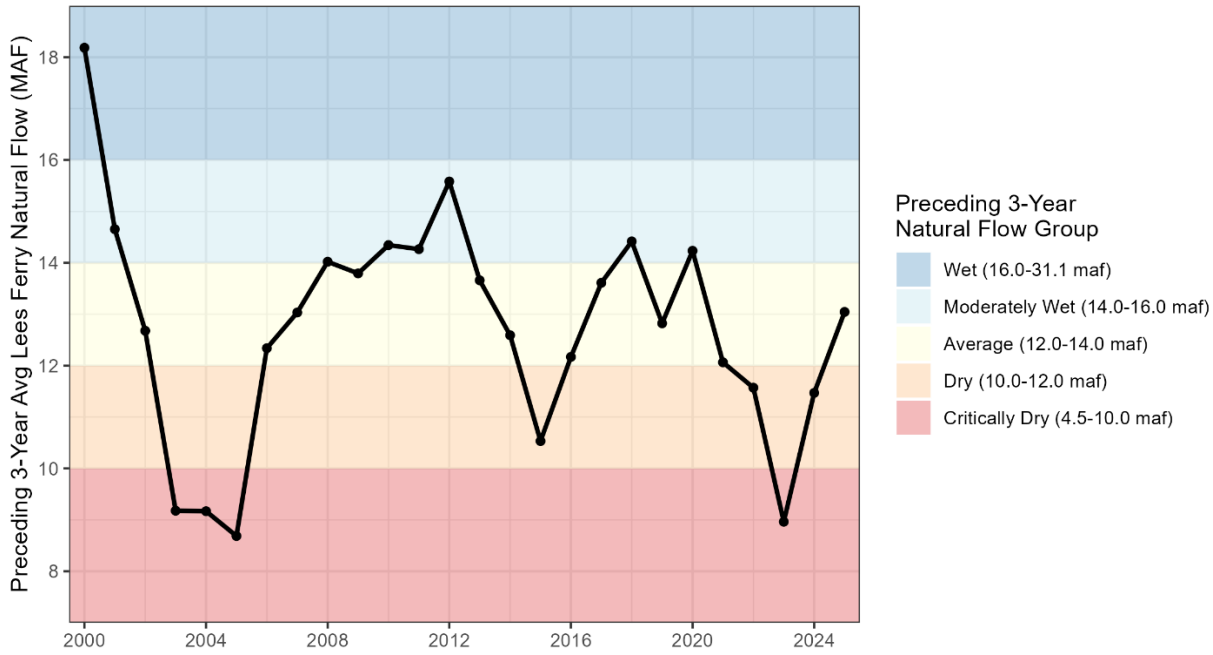
[4] Natural flow at Lees Ferry is a calculated estimate of the flow at that point in the river undepleted by human activities upstream (e.g., reservoir evaporation and regulation, consumptive use). Given that over 90 percent of the total water in the system originates upstream of Lees Ferry, it is a good proxy for the amount of water available to the system overall. This makes it a useful way to categorize hydrology traces.

[5] The 3-year average is used because it is long enough to show impacts from multiple years of moderately challenging hydrology yet short enough to capture the impacts of annual extremes.

Table 3-4
Colorado River Flow Categories

Flow Category Name	Range of Preceding 3-Year Average Lees Ferry Natural Flows (maf)	Percent of Modeled Years in Flow Category	Number of Observed Years in Flow Category, 2000–2025
Wet	16.0–31.1	17	1
Moderately Wet	14.0–16.0	20	7
Average	12.0–14.0	25	11
Dry	10.0–12.0	21	3
Critically Dry	4.5–10.0	17	4

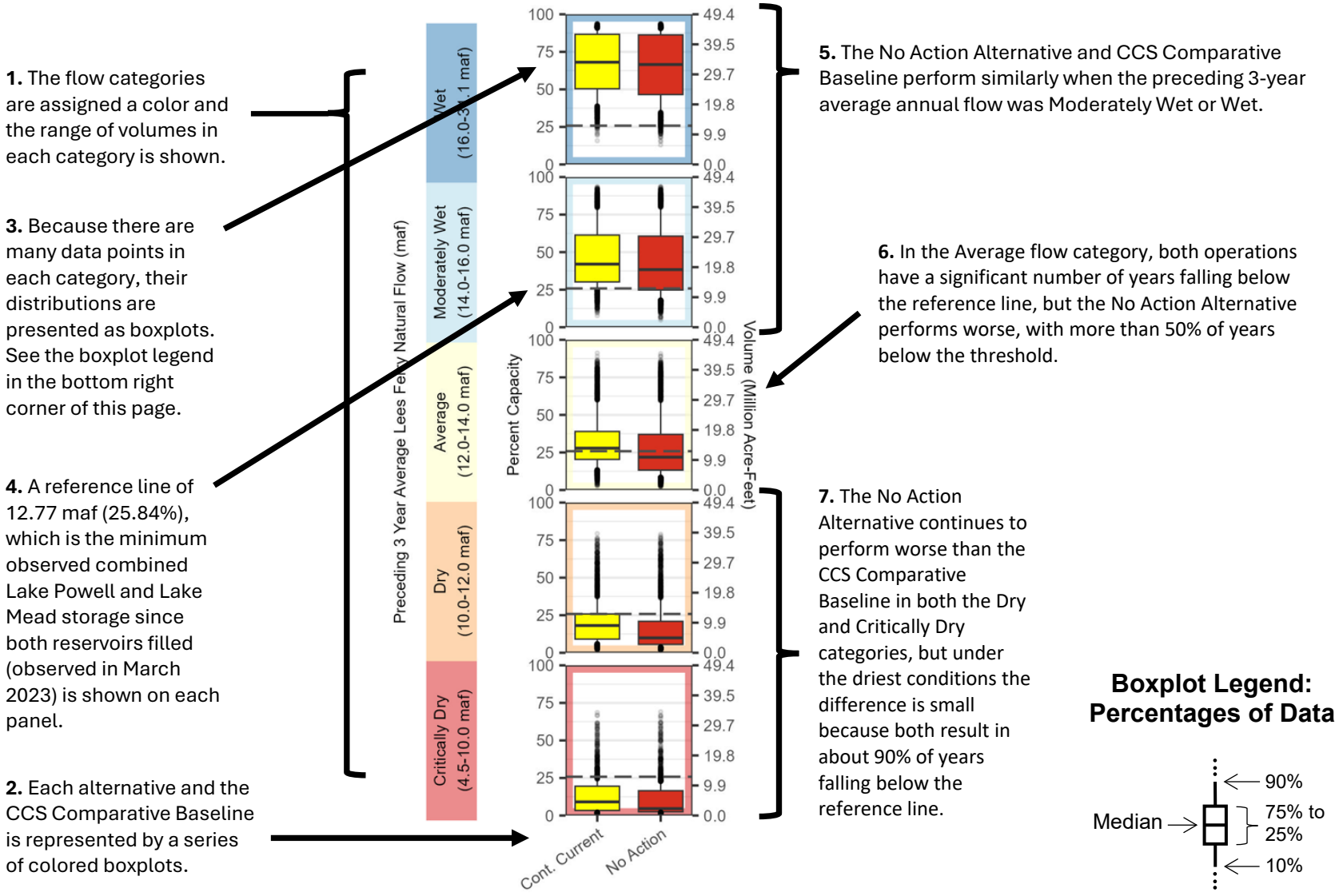
Figure 3-1
Preceding 3-Year Average Lees Ferry Natural Flow, 2000 to 2024



A sample conditional boxplot figure with annotations for guidance is provided in **Figure 3-2,** Sample Conditional Boxplot for WY Minimum Combined Storage of Lake Powell and Lake Mead. **Figure 3-2** has numbered annotations to describe the features of the figure and provide an example summary of what the figure shows about the comparison between the No Action Alternative and the CCS Comparative Baseline. Reading the text in numerical order will provide the clearest understanding.

Conditional boxplots in the impacts analysis will show these two operations alongside the action alternatives. Additionally, reference lines representing values of interest (e.g., historical values or critical thresholds) will be shown with dashed lines. Conditional boxplots will be accompanied by tables of values captured in the boxplots to ensure that precise statistics are communicated.

Figure 3-2
Sample Conditional Boxplot for WY Minimum Combined Storage of Lake Powell and Lake Mead



The connection between system outcomes and hydrologic conditions is clear in the conditional boxplots because the data is sorted by the preceding 3-year average hydrology. To determine which hydrologic categories to focus on and which impacts to contemplate as reasonably foreseeable, the recently observed conditions presented in **Figure 3-1** and **Table 3-4** offer useful context. The Average category is the most common since 2000, while the Wet category is the least common. There have been as many combined instances of Dry and Critically Dry conditions (seven) as there have been instances of Moderately Wet (though, notably, most of the Moderately Wet instances were close to being Average). Recent history combined with the increasing temperature trend, which is associated with lower streamflow, suggests that focusing more on the Average and Dry categories is warranted. However, Critically Dry conditions have been observed and could become more common.

Within each flow category, the distribution of data provides a connection to conditions that occurred before the 3 years used to sort the data into categories: the higher end of a distribution is likely the result of wetter conditions preceding the 3 years, and the lower end of a distribution is likely the result of drier conditions preceding the 3 years. Considering that 20 out of 24 years since 2000 have fallen in the Moderately Wet, Average, and Dry flow categories, it is prudent to focus on specific portions of the distribution within each flow category: the 25th to 75th percentiles (the colored portions of the boxes) are most relevant, since the high and low ends of the distributions are representative of extreme conditions occurring before the 3 years used to sort the data into the flow categories.

Robustness Heatmaps

A robust alternative achieves the preferred minimum performance level under a wide range of future conditions. Robustness heatmaps show the alternatives' ability to meet different levels of performance over one or more decades in the wide range of potential future conditions used in the analysis. Since there are many ways to analyze performance for each resource, there are many opportunities to define meaningful levels of performance. A definition for a single level of performance requires three components: the modeled outcome of a system variable over a time period (i.e., a timeseries), a threshold, and a frequency of meeting the threshold over the specified period.

When a simulated (or modeled) future meets the specified level of performance, it is considered a "successful future." Under each alternative, the percentage of futures (out of 400 modeled futures) that are successful provides information about how robust the alternative is. A large percentage of successful futures (i.e., a high robustness score) means that the alternative is robust (i.e., it performs well) with respect to the specified level of performance; a low percentage of successful futures means that the alternative is not robust with respect to the specified level of performance.

The data that was sorted into categories for the conditional boxplots in **Figure 3-2** can be used in an example robustness heatmap. Performance levels are defined using the annual timeseries of minimum WY combined storage in Lake Powell and Lake Mead (i.e., the minimum storage recorded in each WY from 2027 through 2060) and comparing the timeseries to the threshold of the minimum observed storage (12.77 maf), where staying above this value is better. The final component of defining a level of performance is the frequency of staying above the minimum observed combined storage (100 percent of years, 90 percent of years, etc.).

Figure 3-3 compares the robustness of the No Action Alternative to the CCS Comparative Baseline with respect to their ability to maintain different levels of performance in combined Lake Powell and

Lake Mead storage. It is annotated using numbered descriptions as a guide to the features of the figure and a summary of findings. Reading the text in numerical order will provide the clearest understanding.

In **Figure 3-3**, each row represents a different level of performance. This is useful because individuals can have different opinions about what level of performance is necessary for a given resource. In this case, they could focus on the row that best aligns with their preference. At the same time, it is useful for resource experts to identify a 'preferred minimum level of performance,' which is identified in **Figure 3-3** by the purple box. In this example, the preferred minimum performance level is for the combined storage of Lake Powell and Lake Mead to stay above 12.77 maf in at least 90 percent of years. The preferred minimum performance level is also the basis for vulnerability analysis, as described in the next section.

This type of figure is referred to as a "heatmap" because clusters of colors provide an easy way to identify regions of robustness or lack of robustness across the alternatives. Robustness heatmaps contain a large amount of information, but a quick scan of the rows and columns can reveal key conclusions about robustness. The analysis in this chapter and in the technical appendices uses heatmaps covering four different modeling periods: the full 34-year modeling period (2027-2060) and three approximately equal sub periods. This provides insight into how different alternatives perform in smaller timespans. Importantly, the early sub period (2027-2039) captures how the dry conditions leading up to 2027 affect robustness and corresponds approximately to the length of the Preferred Alternative.

Key visual tips to quickly interpret robustness heatmaps: Every column of colors represents the robustness of an alternative across different levels of performance in a given resource. The more blue there is in a column, and the darker the blue, the more robust an alternative is; a large amount of orange or red, and especially dark red, means an alternative is not robust with respect to a specific type of performance.

For all modeling periods (the full modeling period and individual sub periods), approximately 75 percent of the 400 hydrology traces had an average annual flow lower than the 1906–2025 average of 14.6 maf. Across all periods, approximately 50 percent of traces had an annual average flow lower than the 1988–2024 average, and more than 25 percent of traces had an average that is lower than the 2000–2024 average. Over the subperiods, the 25th percentiles, 10th percentiles, and the driest traces became drier.

The distributions of these statistics can be roughly mapped to robustness percentiles to understand the average conditions associated with unsuccessful futures. For example: over the full modeling period, if a resource is sensitive to drier conditions and an alternative has a robustness score of 90 percent, it is unsuccessful in 10 percent of futures and it is reasonable to map this unsuccessful percentage to the driest 10 percent of the average flows, meaning that the failures are most likely occurring in futures where the 34-year average flow is 11 maf or lower. Readers can determine whether these average conditions are reasonably likely to occur, in which case a 90 percent robustness score may not be adequate to avoid negative impacts on the resource. For resources that are sensitive to wet conditions, the higher end of the distribution of average flows should be referenced. Note that these comparisons are only approximations but are useful for providing context to robustness scores.

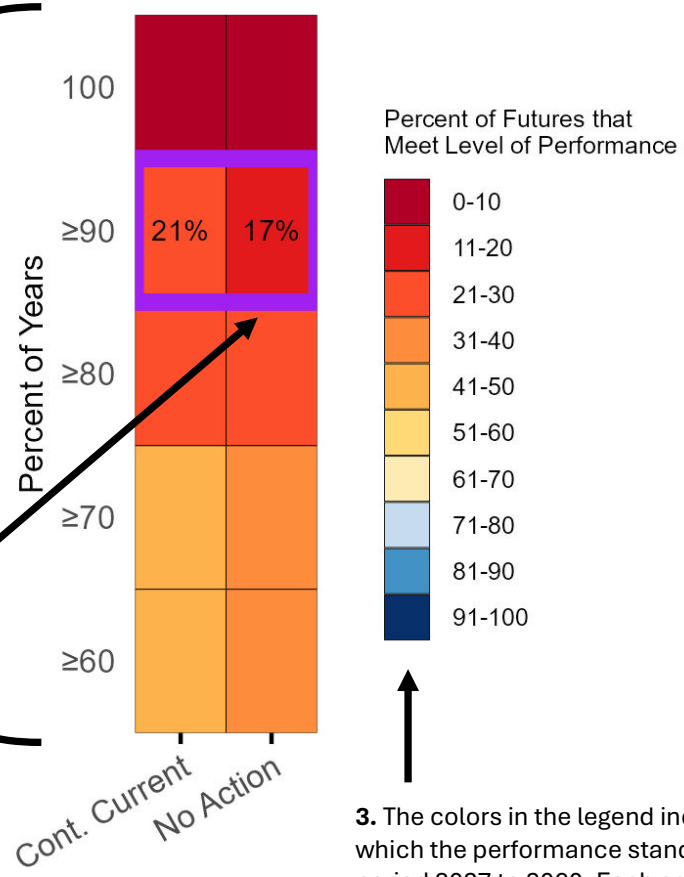
Figure 3-3
Sample Robustness Heatmap for WY Minimum Combined Storage of Lake Powell and Lake Mead.
Percent of futures in which the WY minimum combined storage stays above the historical minimum (12.77 maf) in the percent of years specified by each row

1. The subtitle describes the time-series, threshold, and frequency used to calculate *robustness* (i.e., the percentage of 400 futures that meet the performance requirement).

4. The rows in the heatmap capture different levels of performance. The highest row is the hardest level of performance to achieve (colors are more likely to be red, orange or yellow) and the lowest row is the easiest (colors are more likely to be blue). In this example, each row represents a frequency of keeping combined Lake Powell and Lake Mead storage above the observed minimum.

5. The purple highlighted row denotes the *preferred minimum performance*. This row is the focus for figure descriptions and is the performance level used in vulnerability bar plots.

2. Each alternative and the CCS Comparative Baseline has a column of "cells" that are colored based on the legend.



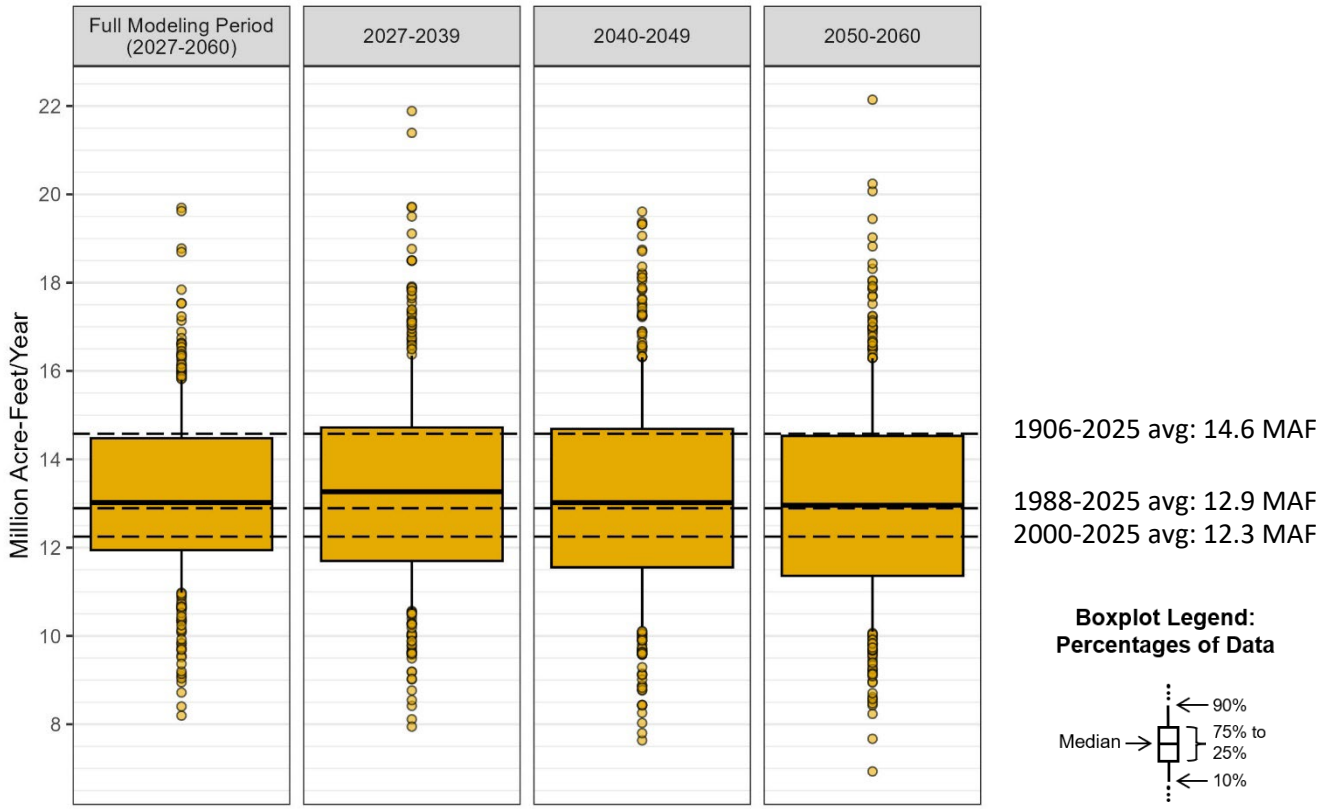
3. The colors in the legend indicate the percentage of futures out of 400 in which the performance standard in each row is met across the time period 2027 to 2060. Each cell in the heatmap has a color corresponding to the robustness of an alternative with respect to the performance standard in that row. Higher percentages (darker blues) indicate higher robustness.

6. The ability of different alternatives to maintain a reasonable minimum amount of storage in Lake Powell and Lake Mead is an important consideration when evaluating their performance. Here, the observed minimum volume of 12.77 maf is taken as a significant threshold, and the preferred minimum performance is to stay above that threshold in at least 90% of years across the 34-year simulation period (purple highlighted row). The CCS Comparative Baseline achieves this level of performance in 17% of futures, so it is slightly more robust than the No Action Alternative which only achieves it in 21% of futures. Both increase in robustness as the performance standard is lowered (looking down the rows), with CCS Comparative Baseline achieving above 40% robustness (light orange cell) when the frequency of staying above the observed minimum storage is relaxed to 60% of years (bottom row).

Assessing which alternatives are in shades of blue (generally robust) and which are in shades of yellow, orange, or red (generally not robust) for a given level of performance provides a basic level of information that is sufficient for comparison. To apply judgment about what robustness score is adequate, it is beneficial to understand the statistical distribution of the underlying hydrology.

Figure 3-4 shows annual average flows by trace for the full 400-trace hydrology ensemble over different time periods and compares them to historical averages. In the first subperiod (second panel from the left) the distribution is slightly higher at the median and 75th percentiles. This is a statistical artifact from several of the constituent ensembles, not a prediction that supply could increase between 2027 and 2039.

Figure 3-4
Average Annual Lees Ferry Natural Flow by Trace for 400-Trace Hydrology Ensemble over Different Time Periods



Vulnerability Bar Plots

Vulnerability bar plots provide complementary analysis to the robustness heatmaps by identifying the specific hydrologic conditions in which each alternative is likely to succeed or fail the preferred minimum performance level[6] (recall, the preferred minimum performance is shown by the purple-

[6] Vulnerability analysis considers if the performance levels are violated any time during the 34-year modeling period. Using the full modeling is preferred such that one hydrology statistic can accurately predict if an alternative will meet the performance level. A decadal-based analysis (like what is included in some robustness heatmaps) would require a multi-dimensional prediction accounting for reservoir storage at the start of each decade, which varies by alternative and hydrology, making it difficult to compare alternatives.

outlined row of the heatmap). For example, the heatmap in **Figure 3-3** shows that the CCS Comparative Baseline successfully meets the preferred minimum performance level in 21 percent of futures, meaning that the CCS Comparative Baseline is unsuccessful in the remainder of the futures (79 percent of futures). Vulnerability analysis uses information about both the successful and the unsuccessful futures to identify hydrologic conditions (via statistical characteristics) that are most skillful at predicting the different outcomes. The hydrologic statistical characteristics tested are:

- the driest 10-year average Lees Ferry flow over a 34-year hydrology trace
- the median 10-year average Lees Ferry flow over a 34-year hydrology trace
- the wettest 10-year average Lees Ferry flow over a 34-year hydrology trace

Statistics based on 10-year averages were determined to be highly accurate at separating successful from unsuccessful futures and provide information on a time-scale relevant to the Preferred Alternative (which is a 10-year decision framework). The driest 10-year average is most frequently the most skillful predictor because it is highly correlated with the undesirable resource outcomes that occur due to dry hydrology. For information about other predictors and how they are tested, refer to **Appendix E**, DMDU Overview and Approach.

Once a skillful predictor is identified, the alternatives can be described in terms of the hydrology conditions associated with undesirable performance (i.e., the conditions in which an alternative is vulnerable). Alternatives will have different vulnerabilities because of their different approaches to operating the reservoirs. Conditions associated with vulnerability can then be compared to conditions that have occurred in the past and a range of conditions that could potentially occur in the future; if conditions that have already occurred are similar to those associated with vulnerability under an alternative, the conclusion is that the undesirable impacts are reasonably likely to occur in the future.

Figure 3-5 compares the vulnerability of the No Action Alternative and the CCS Comparative Baseline with respect to avoiding undesirable performance in combined Lake Powell and Lake Mead storage (i.e., falling below the historical minimum in more than 10 percent of years). The figure also shows how each alternative's vulnerability compares to conditions that have occurred in the past or could potentially occur in the future. It is annotated using numbered descriptions as a guide to the features of the figure and a summary of findings. Reading the text in numerical order will provide the clearest understanding.

Vulnerability bar plots capture complex information, but a brief visual inspection can provide the key conclusions about whether undesirable impacts could be reasonably expected under a given alternative.

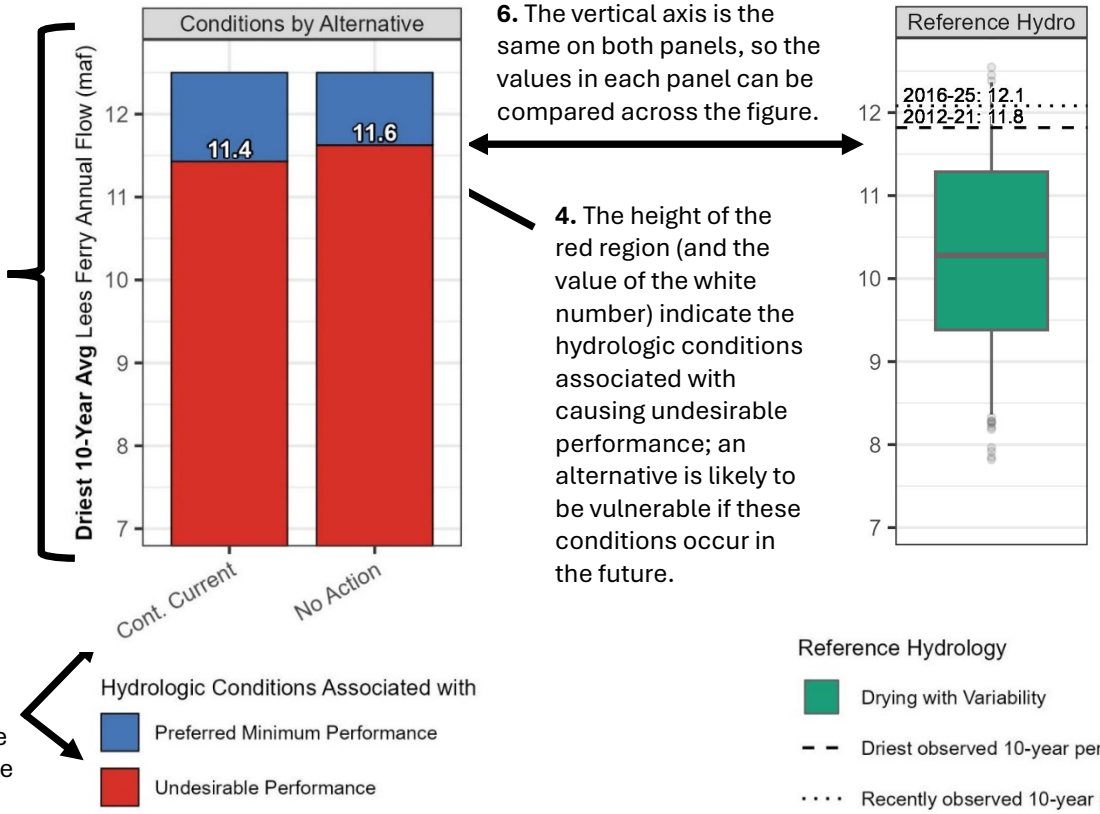
Key visual tips to quickly interpret vulnerability bar plots: Every alternative is linked to a bar that is divided into blue and red; the larger the red portion, the wider the range of hydrology conditions in which the alternative is vulnerable. If the red portion of the bar encompasses, or is close to, conditions that have already occurred according to the reference hydrology panel, undesirable performance in that resource is likely to occur. (If a bar is completely blue, none of the conditions tested caused vulnerability and the alternative is robust.)

Figure 3-5
Sample Vulnerability Bar Plot for WY Minimum Combined Storage of Lake Powell and Lake Mead. Conditions that could cause Combined Lake Powell and Lake Mead storage to fall below the historical minimum in more than 10 percent of years

1. The subtitle provides a definition of undesirable performance adapted from the purple preferred minimum performance row in the heatmap.

3. The vertical axis is based on the streamflow statistic that is a skillful predictor of the alternatives' ability to meet the preferred minimum performance. In this case, the driest 10-year average Lees Ferry annual flow was a good predictor. The range of the axis captures the full range of worst 10-year droughts tested.

2. Each alternative and the CCS Comparative Baseline have a vertical bar divided into conditions associated with meeting the minimum preferred performance (blue region) and conditions that are associated with undesirable performance (red region).



6. The vertical axis is the same on both panels, so the values in each panel can be compared across the figure.

4. The height of the red region (and the value of the white number) indicate the hydrologic conditions associated with causing undesirable performance; an alternative is likely to be vulnerable if these conditions occur in the future.

5. The Reference Hydro panel provides two types of context for the height of the red region for each alternative. First, there are two historical reference lines: the statistics for the most recent period and the statistics for the worst observation in the relevant statistic. The second type of context shows the distribution of this streamflow statistic represented in the Drying-with-Variability ensemble, which is a set of 100 hydrology traces whose significance is described in Section 3.2.6 and Appendix F.

7. The No Action Alternative is likely to be vulnerable to undesirable performance if the future includes a 10-year drought averaging 11.6 maf or less; conditions similar to these have already occurred in the observed record. The CCS Comparative Baseline is likely to be vulnerable if the future includes a 10-year drought averaging 11.4 maf or lower, which is close to conditions that have already occurred. About 90 percent of the hydrology sequences in the Drying-with-Variability ensemble have drier droughts than those likely to cause vulnerability under these two operations.

The "reference hydrology" panel introduced in **Figure 3-5** is included in every vulnerability bar plot to provide context for interpreting the likelihood of the conditions associated with vulnerability. The historical reference lines are the first component of the context, and anytime an alternative is vulnerable to conditions that have already been observed, it is reasonable to assume these conditions can occur again.

The second component of the context is the boxplot that shows projections about potential future conditions. These projections are based on the "Drying-with-Variability" ensemble, which is a 100-trace statistically generated ensemble that represents conditions that may occur in the future.[7] Long-term planning in the Basin must consider the significant potential for a future with more frequent, sustained, and/or severe dry periods and a downward trend in average flows, but this does not preclude the occurrence of wet years. The Drying-with-Variability ensemble was designed to capture this by combining information about the observed temperature trend, temperature's impact on the translation of precipitation into streamflow, and the sequencing of wet and dry periods from paleo reconstructed data while preserving the potential for infrequent but significant wet years.

For every vulnerability bar plot, the two sources of hydrologic context – observed hydrology and the Drying with Variability ensemble – are used to make a summary statement about whether the Representative Preferred Alternative is reasonably likely or unlikely to be vulnerable absent additional action. This statement combines objective analysis of conditions likely to cause failure and Reclamation's expert judgment considering how those conditions compare to the past and to a reasonable expectation of future hydrology given current trends.

Figure 3-6 provides the distribution of statistics across the 100 traces in the Drying-with-Variability ensemble and compares them to the worst statistic in the observed record (1906–2025). For the driest 1-year flow, over 50 percent of Drying-with-Variability traces have a drier year than the lowest observed flow, with the lowest single-year flow in the ensemble falling below 5 maf. In the 2-to-10-year windows, 60 percent of traces or more are drier than the worst observed statistic; for the driest 10-year volume, approximately 85 percent of traces contain drier decades than the worst observed decade, which occurred from 2012 to 2021.

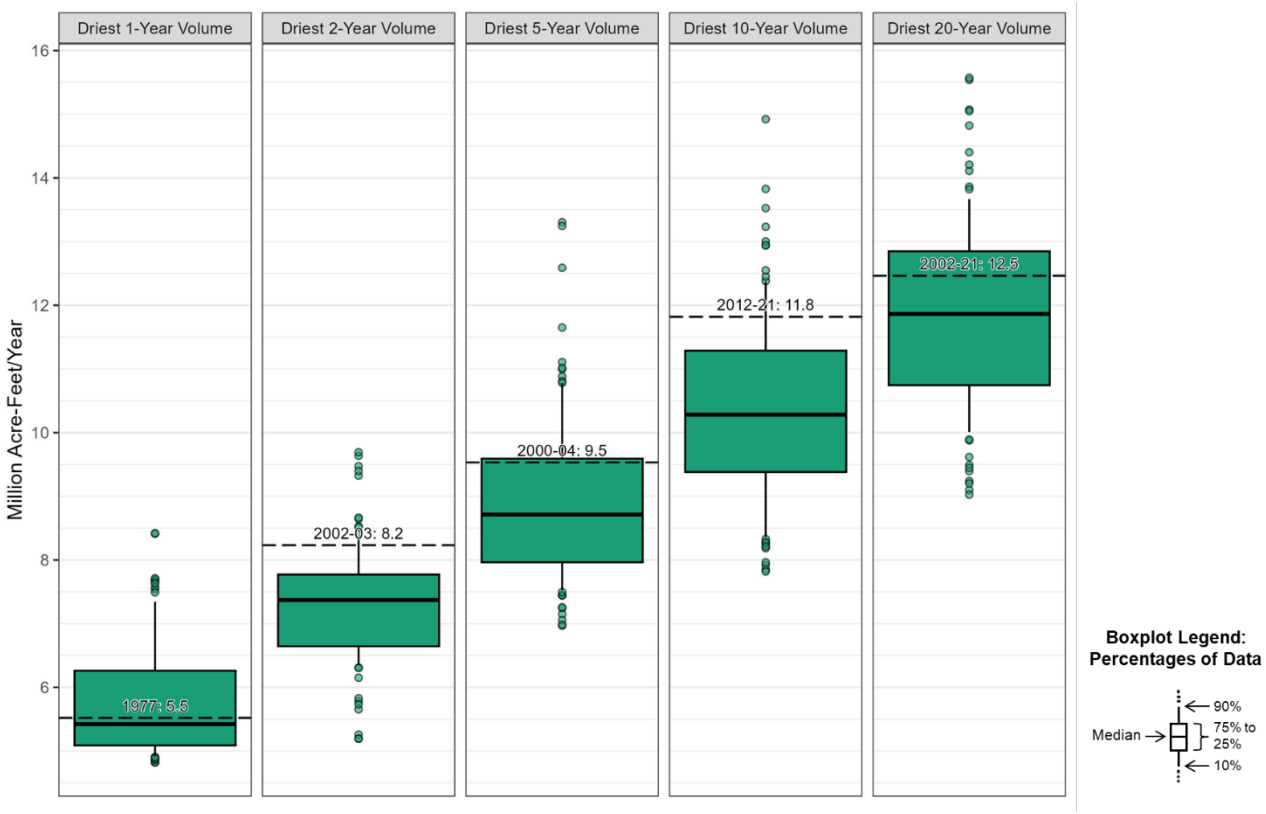
The purpose of describing the narrative, underlying data, and statistics of the Drying with Variability ensemble in the introduction to DMDU figures is to highlight that vulnerability bar plots provide a large amount of information that allows readers to use their judgment in determining the likelihood of negative resource impacts. The vulnerability bar plots combine information about the conditions in which each alternative is vulnerable, historical context, and the potential for a drier future.

3.2.7 Salton Sea

During scoping and public review of the Draft EIS, Reclamation received comments requesting analysis of impacts to the Salton Sea. The Salton Sea is a terminal lake in Riverside and Imperial Counties, California. Lake levels are influenced by runoff from the surrounding Imperial Valley and Coachella Valley watersheds, as well as agricultural drainage from the IID and CVWD. As explained below, analysis of impacts to the Salton Sea is not included in this EIS.

[7] For additional information about this ensemble, refer to **Appendix F**, Approach to Hydrologic Uncertainty.

Figure 3-6
Key Statistics for the Drying with Variability Ensemble



The Salton Sea acts as a terminal sump for agricultural drainage; therefore, reductions in agricultural runoff could impact Salton Sea elevations, which, in turn, could impact air quality and shoreline wildlife habitat. Agriculture in the IID and CVWD service areas, as well as smaller non-agricultural uses, are sustained by Colorado River water diverted at the Imperial Dam and delivered via the All American and Coachella Canals. In recent years, total diversions of Colorado River water were approximately 2.8 mafy at the Imperial Dam (California Natural Resources Agency 2024).

Over the past 20 years, inflows to the Salton Sea have declined from 1.3 mafy to approximately 1.1 mafy (California Natural Resources Agency 2024), primarily related to California's reduced usage of Colorado River water due to the prolonged drought in the Basin and changing agricultural practices, including implementation of water conservation programs.

The California Natural Resources Agency established the Salton Sea Management Program (SSMP) to oversee restoration efforts at the Salton Sea. Currently, the SSMP is working with local, state, tribal, and federal partners to implement the first phase of habitat restoration projects to establish at least 14,900 acres of aquatic habitat and up to 14,900 acres of vegetated habitat by the year 2028 (USACE 2024). Additionally, the SSMP released a long-range plan to address future recession of the Salton Sea beyond the year 2028 (California Natural Resources Agency 2024). The goal of the plan is to protect or improve air quality, water quality, and wildlife habitat to prevent or reduce health and environmental consequences anticipated from the long-term recession of the Salton Sea shoreline (California Natural Resources Agency 2024).

Given that inflows into the Salton Sea depend on a highly managed system, subject to growing water demands, and uncertain weather patterns and water polices, the SSMP used a range of projected annual net inflows to the Salton Sea as baselines for analysis: (1) high probability of inflow at 889,000 af, (2) low probability inflow at 684,000 af, and (3) very low probability at 444,000 af. These flows are used to project the future baseline of the Salton Sea and the restoration needs. The SSMP's long-range plan specifically acknowledges the uncertainty around policy decisions on this Colorado River Post-2026 process and is a reason for using a range of net inflows.

The SSMP's long-range plan is informing the scope of the Imperial Streams and Salton Sea Ecosystem Restoration Feasibility Study and NEPA compliance that the USACE is currently preparing. Once that process is complete, state and federal funding will be pursued to support the resultant design and construction of restoration projects, beginning around 2028.

For this Post-2026 process, Reclamation's action is to develop operational guidelines for the storage and release of water through Lake Powell at Glen Canyon Dam and Lake Mead at Hoover Dam. Reclamation's contracts with IID and CVWD do not provide Reclamation with the discretion to determine how individual water users within these districts use or allocate their water resources, including user decisions to participate or not participate in conservation programs.

Any reductions of Colorado River water available for diversion at the Imperial Dam for use by IID and CVWD could result in less available water for agriculture and, depending on the conservation activity or how the reduction would be implemented, subsequent drainage to the Salton Sea. While Reclamation cannot control Basin hydrology, there could be policy decisions that result in shortages.

In summary, analysis of impacts to the Salton Sea are not included in this EIS for the following reasons:

1. Any resultant impacts are within the scope and range of inflows being considered as part of the baseline in the SSMP's long-range plan and the USACE's ongoing NEPA process. While any resultant impacts to the Salton Sea may be accelerated by Post-2026 policies, the overall magnitude of impacts would not change.
2. Reclamation does not manage or control the end use of water after the point of delivery. As such, Reclamation has no management authority over the distribution of end use or allocation by these water districts and individual users, including user decisions to participate in conservation programs. The State of California oversees management of the Salton Sea, and Reclamation has no management or enforcement authority over inputs to the Sea. Reclamation would need new authorities and compliance to implement any policies that change how water shortages are distributed to IID and CVWD.[8]

[8] Reclamation's potential contribution of funds through contribution agreements does not affect the enforcement mechanisms of those state and local authorities.

3.3 Hydrologic Resources

3.3.1 Affected Environment

Overview and Study Area

This section summarizes the Basin's hydrology from the full pool elevation of Lake Powell to the SIB with Mexico. It also includes groundwater under direct influence of the Colorado River and the Lower Basin reservoirs. For a more detailed account of the affected environment for the hydrologic resources, please see **TA 3**, Hydrologic Resources.

Key Drivers and Trends

Worsening drought conditions have been a major driver for changes to hydrologic resources in the Basin. Since 2000, the Basin has experienced persistent drought conditions, exacerbated by higher temperatures, resulting in increased evapotranspiration, reduced soil moisture, and ultimately reduced runoff (Lukas and Payton 2020). The flow in the Colorado River is highly variable from year to year because of variations in precipitation in the Basin. However, the Basin is currently experiencing a prolonged period of drought; 2000 to 2024 was the driest 25-year period in more than a century. A paleo reconstruction of Colorado River streamflow at Lee Ferry, Arizona, back to 762 current era (CE), indicates that the recent 25-year period has lower streamflow than any other period in the last 1,200 years (Meko et al. 2007). These conditions have led to a cumulative streamflow deficit of about 70.0 maf relative to twentieth-century conditions (Reclamation 2025b).

Operational Impacts

The overall characteristics and connectivity of the Basin remain unchanged from when the 2007 Final EIS was issued. However, since 2007, key operational changes have affected hydrologic resources. Domestic agreements specifying such operations include the 2007 Interim Guidelines (supplemented in 2024), the 2016 Glen Canyon Dam LTEMP (supplemented in 2024), and the 2019 DCP. More details on operational changes since 2007 can be found in **Section 1.8.2.1**, The Law of the River.

Reservoirs and River Reaches Overview

Upper Basin – CRSP Upper Initial Units

The 1956 CRSPA created four major Upper Basin reservoirs to support Colorado River Compact compliance: Flaming Gorge in Utah, Navajo in New Mexico, Blue Mesa in Colorado, and Lake Powell in Utah and Arizona. The CRSP Upper Initial Unit reservoirs include Flaming Gorge, Navajo, and Blue Mesa. Total live storage volume of the CRSP Upper Initial Units is 6.15 maf. Prolonged drought and low runoff conditions prompted the 2019 DROA (a component of the 2019 DCP) to allow strategic releases from the CRSP Upper Initial Units reservoirs to protect elevations at Lake Powell. As described in **Section 3.2.1**, operations at the CRSP Upper Initial Units specifically contemplated in the Final EIS alternatives are intended to remain within the scope of the existing RODs. Accordingly, the Final EIS does not expand the geographic scope of analysis upstream of Lake Powell.

Lake Powell and Glen Canyon Dam

Lake Powell is a reservoir located in southern Utah and northern Arizona. The water surface operating range of Lake Powell is between 3,490 feet (corresponding to the minimum power pool) and 3,700 feet (corresponding to the top of Glen Canyon Dam spillway). The total live storage capacity of Lake

Powell at the full pool elevation of 3,700 feet is 23.31 maf (excluding 1.9 maf of flood control space). Due to persistent drought, storage levels in Lake Powell have declined, particularly in the early 2000s and from 2020 to 2022, when elevations were at an all-time low since filling. Should elevations drop below 3,490 feet, routine operations of Glen Canyon Dam would be discontinued, and hydropower could no longer be produced. Releases can be made through the river outlet works down to elevation 3,370 feet (corresponding to dead pool) below which water cannot be delivered downstream. However, the outlet works are not designed nor intended for long-term use at low reservoir levels. The infrastructure at Glen Canyon Dam is described further in **Section TA 3.1.3**, Lake Powell and Glen Canyon Dam.

Unregulated inflows to Lake Powell from the Upper Basin vary year to year based on hydrologic conditions. A period of drought that began in 2000, exacerbated by increasing temperatures, has led to a 20 percent decrease in average annual Upper Basin (at Lees Ferry) natural flows (Reclamation 2025a). This continued dry period and decrease in inflows in recent years have resulted in Lake Powell approaching critically low elevations. Drought conditions from 2020 to 2022 triggered the need to supplement the 2007 Interim Guidelines with near-term provisions for addressing extremely low reservoir levels. The result was the 2024 ROD, providing for lower releases from Lake Powell. Since the implementation of the 2007 Interim Guidelines, the water surface operating range of Lake Powell has been between a low of 3,519.92 feet (occurring in 2023), and a high of 3,660.9 feet (occurring in 2011). Historical low and high elevations in Lake Powell are shown in **Figure TA 3-1** in **TA 3**, Hydrologic Resources. Annual Glen Canyon Dam releases from Lake Powell averaged 9.75 maf from 1996 through 2007, but have since averaged 8.62 maf (ranging from 7.00 maf to 12.52 maf from 2008 through 2025).

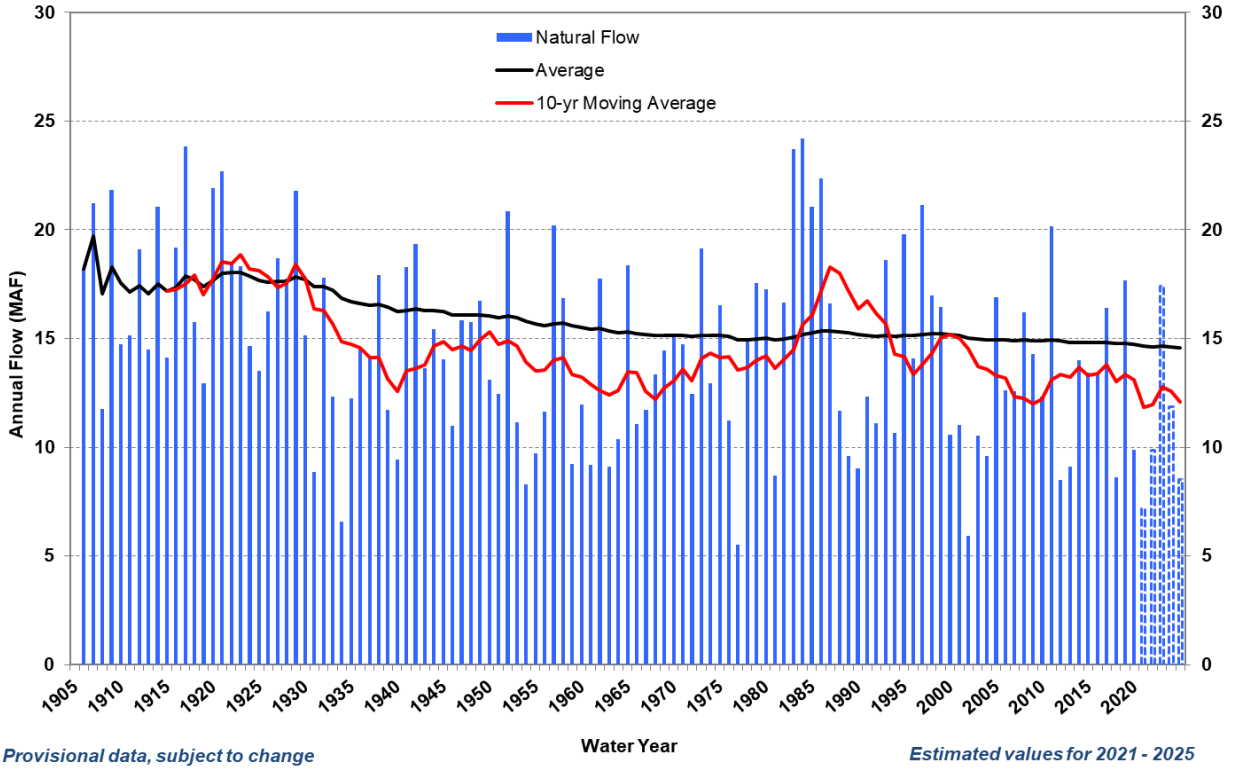
Lees Ferry Gaging Station and Lee Ferry Compact Point

The Lees Ferry Gaging Station is located in Arizona, approximately 15.9 river miles (RMs) downstream of Glen Canyon Dam. This differs from the Lee Ferry Compact Point, which is the division point between the Upper Basin and Lower Basin as established by the 1922 Colorado River Compact. The Lee Ferry Compact Point is located a few miles downstream of the Lees Ferry Gaging Station and the confluences with the Paria River. **Figure TA 3-2** in **TA 3**, Hydrologic Resources shows the difference between the two locations.

From 1906 to 2007, the average annual natural flow at the Lees Ferry Gaging Station was calculated to be 14.9 maf and ranged from 5.4 maf to 24.4 maf. Since the implementation of the 2007 ROD (2008 to 2025), the annual natural flow at the Lees Ferry Gaging Station averaged 12.7 maf and has ranged from a low of 6.7 maf (2021) to 20.3 maf (2011). **Figure 3-7** below shows the WY natural flows calculated at the Lees Ferry Gaging Station for 1906 through 2025.

Natural flows at Lees Ferry Gaging Station are calculated based on observed (gage) flow and corrected by Reclamation for upstream reservoir changes in storage and release, losses including evaporation, and depletions due to agriculture and domestic uses.

Figure 3-7
Colorado River Natural Flow at Lees Ferry Gaging Station, Arizona (1906-2025)



Source: Reclamation 2025f

Lake Mead, Lake Mohave, Lake Havasu, Cibola Gage, Imperial Dam, Northerly and Southerly International Boundaries

Approximately 292 miles downstream of Glen Canyon Dam is Lake Mead, formed by Hoover Dam. This reach of the Colorado River includes the Grand Canyon, which is approximately 277 miles long. Flows in this reach primarily consist of flow from Glen Canyon Dam releases but do include minor contributions from perennial tributaries. The two largest tributaries in this reach are the Paria River and the Little Colorado River, which make up approximately 3 percent of the total flows in the Colorado River in this reach (USGS 2025a).

Lake Mead is located in the Black Canyon, on both sides of the Arizona-Nevada state line near Las Vegas. The water surface elevation operating range for Lake Mead is between 895 feet (corresponding to dead pool) and 1,229 feet (corresponding to the top of the Hoover Dam spillway). The total live storage capacity of Lake Mead at the full pool elevation of 1,219.6 feet is 26.12 maf (excluding approximately 1.5 maf of flood control space). Lake Mead has a minimum power pool elevation of 950 feet, below which releases occur only through the river outlet works and hydropower cannot be generated. When elevations drop below 895 feet, water is no longer able to be delivered downstream from Hoover Dam.

Since 2007, water surface elevations at Lake Mead have generally declined. Since the implementation of the 2007 ROD, the water surface operating range of Lake Mead has been between a low of 1,040.6

feet (occurring in 2022) and a high of 1,134.5 feet (occurring in 2012). Historical low and high elevations in Lake Mead are shown in **Figure TA 3-5** in **TA 3**, Hydrologic Resources. Annual Hoover Dam releases from Lake Mead ranged from 8.275 maf to 12.781 maf (averaging 10.199 maf) from 1996 through 2007, but have since ranged from 8.515 maf to 9.615 maf (averaging 9.185 maf) from 2008 through 2024.

The 67-mile reach from Hoover Dam to Davis Dam forms Lake Mohave. Lake Mohave is located on both sides of the Arizona-Nevada state line near Bullhead City, Arizona. Flows in this reach are almost entirely comprised of releases from Hoover Dam. The average storage in Lake Mohave has remained constant, at approximately 1.6 maf over the past few decades. Lake Mohave is operated under an existing rule curve that determines specific target elevations at the end of each month. This rule curve was not affected by the 2007 Interim Guidelines, so the average annual water surface elevation at Lake Mohave was approximately 640.8 feet from 1996 to 2007 and 640.9 feet since 2008.

The 84-mile reach from Davis Dam to Parker Dam forms Lake Havasu, which is located on both sides of the California-Arizona state line near Lake Havasu City, Arizona. Flows in this reach primarily consist of releases from Davis Dam, although contributions from the Bill Williams River make up approximately 1 percent of the total flows (USGS 2025b). Lake Havasu provides a forebay and desilting basin that pumps water for delivery to the MWD and CAP service areas. Similar to Lake Mohave, Lake Havasu is operated under an existing rule curve that determines specific target elevations at the end of each month. This rule curve was not changed by the 2007 Interim Guidelines and maintains Lake Havasu's water surface elevation between 445 and 450 feet. While the 2007 Interim Guidelines did not explicitly target Parker Dam operations, decreased inflows to Lake Havasu (as a result of decreased releases from upstream Lake Powell and Lake Mead) have resulted in decreased annual release rates. Since the implementation of the 2007 Interim Guidelines, the average annual releases from Parker Dam have decreased by 1.0 maf.

One hundred five miles downstream of Parker Dam is Reclamation's Cibola Gage. Flows in this reach primarily consist of releases from Parker Dam. Decreased releases from Parker Dam in the last 20 years have resulted in decreased flows in this 105-mile reach. Two major diversion dams are located in this reach: Headgate Rock Dam and Palo Verde Diversion Dam. The impoundments of these dams facilitate the diversion of water for the Colorado River Indian Tribes and the Palo Verde Irrigation District. Current operations keep these reservoirs at constant elevations. Thirty-eight miles downstream from the Cibola Gage is Imperial Reservoir, formed by Imperial Dam. Flows in this reach primarily consist of releases from Parker Dam. Imperial Dam was constructed to raise the water surface elevation enough to provide gravity-controlled flow to meet water deliveries to California via the AAC and to Arizona via the Gila Main Canal. The AAC diverts water for the IID, the CVWD, the Yuma Project, and the City of Yuma. The Gila Gravity Main Canal diverts water for Gila Valley, Yuma Mesa, and the Wellton-Mohawk area. Imperial Dam also regulates deliveries to Mexico.

Five miles downstream of Imperial Dam is Laguna Dam. Originally, Laguna Dam diverted water to the Yuma Project area but then the Imperial Dam was built. The Laguna Dam is now used as a regulating structure for sluicing flows from Imperial Dam and also provides downstream toe protection for Imperial Dam. Flows in this reach primarily consist of releases from Imperial Dam and contributions from the Gila River. Twenty-six miles downstream of Imperial Dam is the NIB between the U.S. and Mexico.

The Morelos Diversion Dam is 1.1 miles downstream of the NIB and impounds the majority of the water supply that is diverted by Mexico into the Reforma Canal. The dam is owned, operated, and maintained by Mexico per the 1944 Water Treaty. To ensure the annual 1.5 maf water delivery under Normal Conditions per the 1944 Water Treaty, the Morelos Diversion Dam operations have not changed as a result of the 2007 ROD. Refer to **Appendix N**, International Border Region of the Colorado River, for more details related to previous binational coordination efforts. Since most of the water is diverted at Morelos Diversion Dam into the Reforma Canal, flows in the Colorado River limitrophe downstream of Morelos Diversion Dam are infrequent. Flows downstream of Morelos Diversion Dam in the limitrophe to the SIB only occur due to Flood Control operations at Hoover Dam, seepage from Morelos Diversion Dam, irrigation return flows, groundwater inflow, and any water released for environmental purposes in the Colorado River Delta. The upper portion of the limitrophe is a gaining reach due to high groundwater levels in adjacent irrigated fields; however, in the southern portions of the limitrophe, groundwater elevations decrease, and it becomes a losing reach.

3.3.2 Environmental Consequences

Methodology

CRSS was used to simulate Basin conditions and account for hydrologic uncertainty through the full analysis period (2060) on a monthly time-step. Reservoir elevations, reservoir releases, and river flows are outputs to the model and are used directly for the results presented in this resource section. To help visualize the different states of modeled futures, results from CRSS are framed using five potential flow condition categories that range from wet hydrologic conditions to critically dry hydrologic conditions. For background and guidance related to figures used in the analysis below (conditional boxplots, robustness heatmaps, and vulnerability bar plots), see **Section 3.2**, Analysis Methods.

Impact Analysis Area

The geographic scope of the hydrologic resources analysis is the Colorado River corridor from the upstream limits of full pool elevation of Lake Powell to the downstream limits of the SIB. Reservoirs upstream of Lake Powell are operated pursuant to their own RODs, which are not altered by the proposed alternatives.

Assumptions

The hydrologic resources results are direct outputs from CRSS. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation. All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (refer to **Appendix S**, Additional Description of Alternatives). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

Impact Indicators

Five impact indicators were used to assess impacts on hydrologic resources due to operational activities: reservoir elevations, system storage, reservoir releases, river flows, and qualitative (descriptive, non-modeled) impacts on groundwater adjacent to reservoirs and river reaches.

Issue 1: Reservoir Elevation

Water surface elevations at Lake Powell and Lake Mead are anticipated to be affected by the various alternatives as a result of changes to operational activities. Water surface elevations at Lake Mohave and Lake Havasu are not anticipated to be affected. The impacts on water surface elevations at each reservoir are summarized below. Refer to **Section TA 3.2.1**, Issue 1: Reservoir Elevations, in **TA 3**, Hydrologic Resources, for details regarding impacts on water surface elevations at Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu.

Under the Average Flow Category, all action alternatives generally maintain reservoir elevations above critical thresholds, but performance diverges significantly as conditions become drier.

Lake Powell Reservoir Elevations

Refer to **Table TA 3-2** in **TA 3** for a list of critical elevations at Lake Powell. A statistical breakdown of CRSS modeling results for end of water year (EOWY) elevations and minimum WY elevations at Lake Powell can be found in **Table TA 3-3** and **Table TA 3-4** in **TA 3**, respectively.

Figure 3-8 below looks at the response of Lake Powell WY minimum elevations and storage volumes, and EOWY elevations and storage volumes, to different hydrologic conditions under different alternatives by looking at the preceding 3-year average of Lees Ferry natural flow. The figure visualizes the same data that is included in **Table TA 3-3** and **Table TA 3-4** in two side by side conditional box plot panels.

At Lake Powell, the critical elevations of 3,500 feet and 3,525 feet, shown as dashed lines, frame the analysis. These elevations are important because they provide a 10-foot and a 35-foot buffer above 3,490 feet—the elevation below which water can only be released through the river outlet works. Operating below 3,490 feet limits the volume of water that can be released, since water can only pass through the river outlet works. As described in **Section 1.8.4.1**, there are infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs. There are additional impacts to hydropower associated with operating below 3,490 feet as this is minimum power pool.

Under the Average Flow Category, all alternatives keep median EOWY elevations well above these thresholds. As conditions dry, the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best, maintaining median EOWY elevations of 3,557 and 3,546 feet respectively even under the Critically Dry Flow Category, while the No Action Alternative (3,478 feet) and Basic Coordination Alternative (3,487 feet) drop below the 3,500-foot threshold.

Figure 3-8
WY Minimum and EOWY Elevations and Storage Volumes of Lake Powell

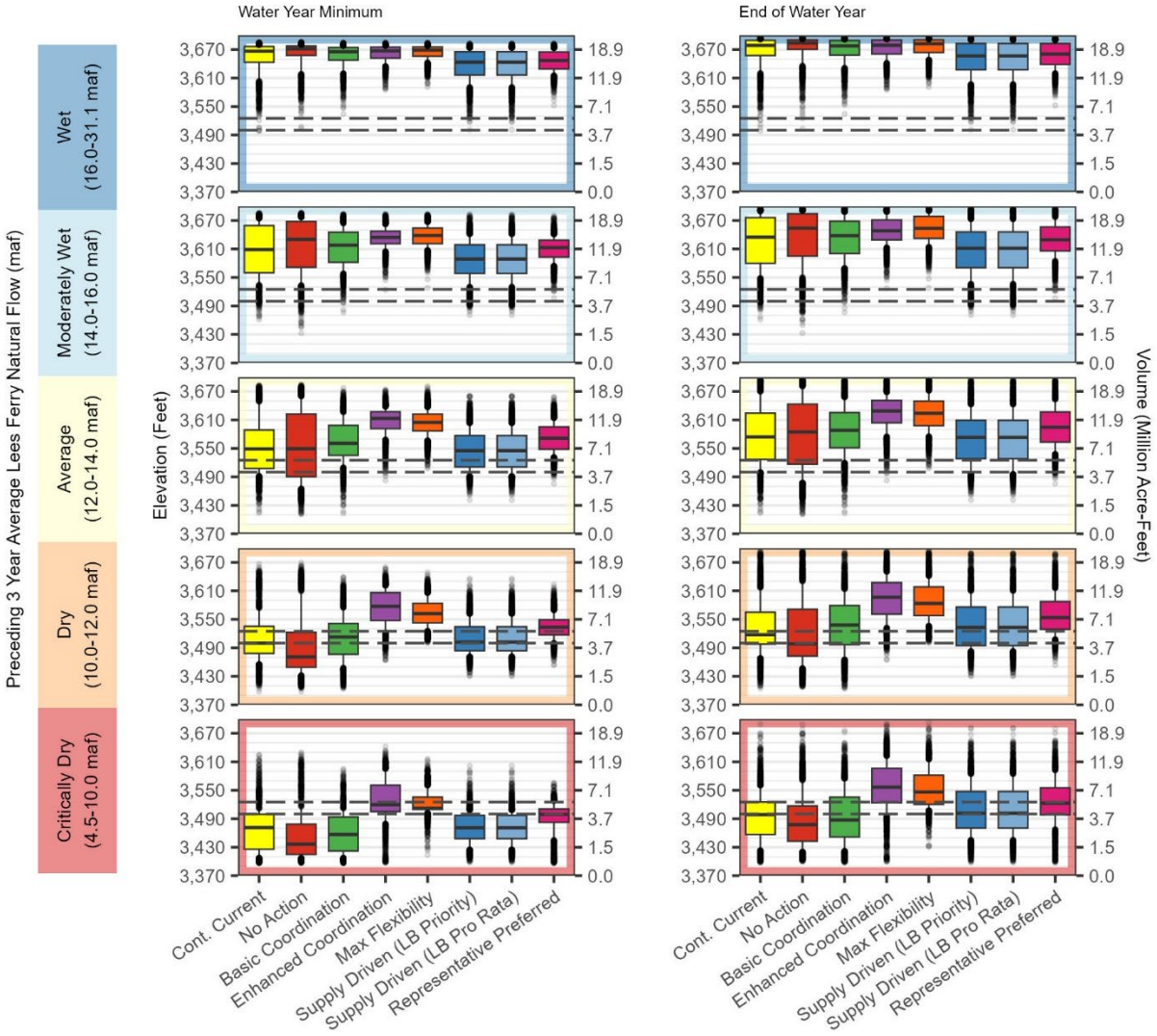
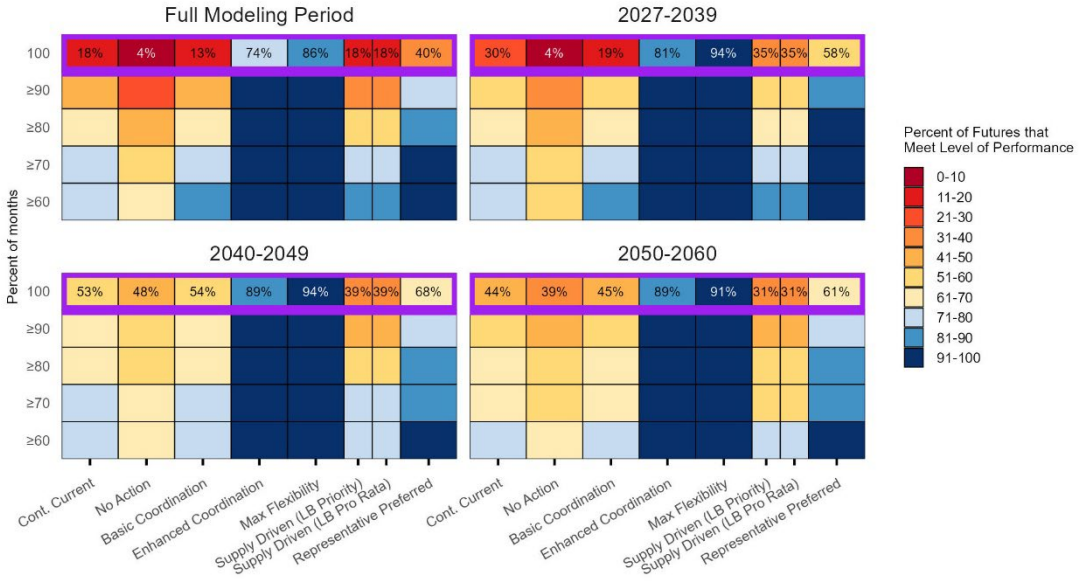


Figure 3-9 compares alternatives with respect to keeping Lake Powell above an elevation of 3,500 feet. As described above, this elevation is important because it provides a 10-foot buffer to protect critical infrastructure, water supply, and hydropower, which are critically impacted at an elevation of 3,490 feet. Over the full 34-year modeling period, the Maximum Operational Flexibility Alternative keeps Lake Powell above 3,500 feet in 100 percent of months in 86 percent of futures, and the Enhanced Coordination Alternative does so in 74 percent of futures. The Representative Preferred Alternative achieves this in 40 percent of futures overall and 58 percent in the critical first decade (2027–2039), ranking third among alternatives. The No Action Alternative is least robust at just 4 percent of futures.

Figure 3-9
Lake Powell 3,500 Feet: Robustness.
Percent of futures in which Lake Powell elevation stays above 3,500 feet in the percent of months specified by each row



Lake Mead Reservoir Elevations

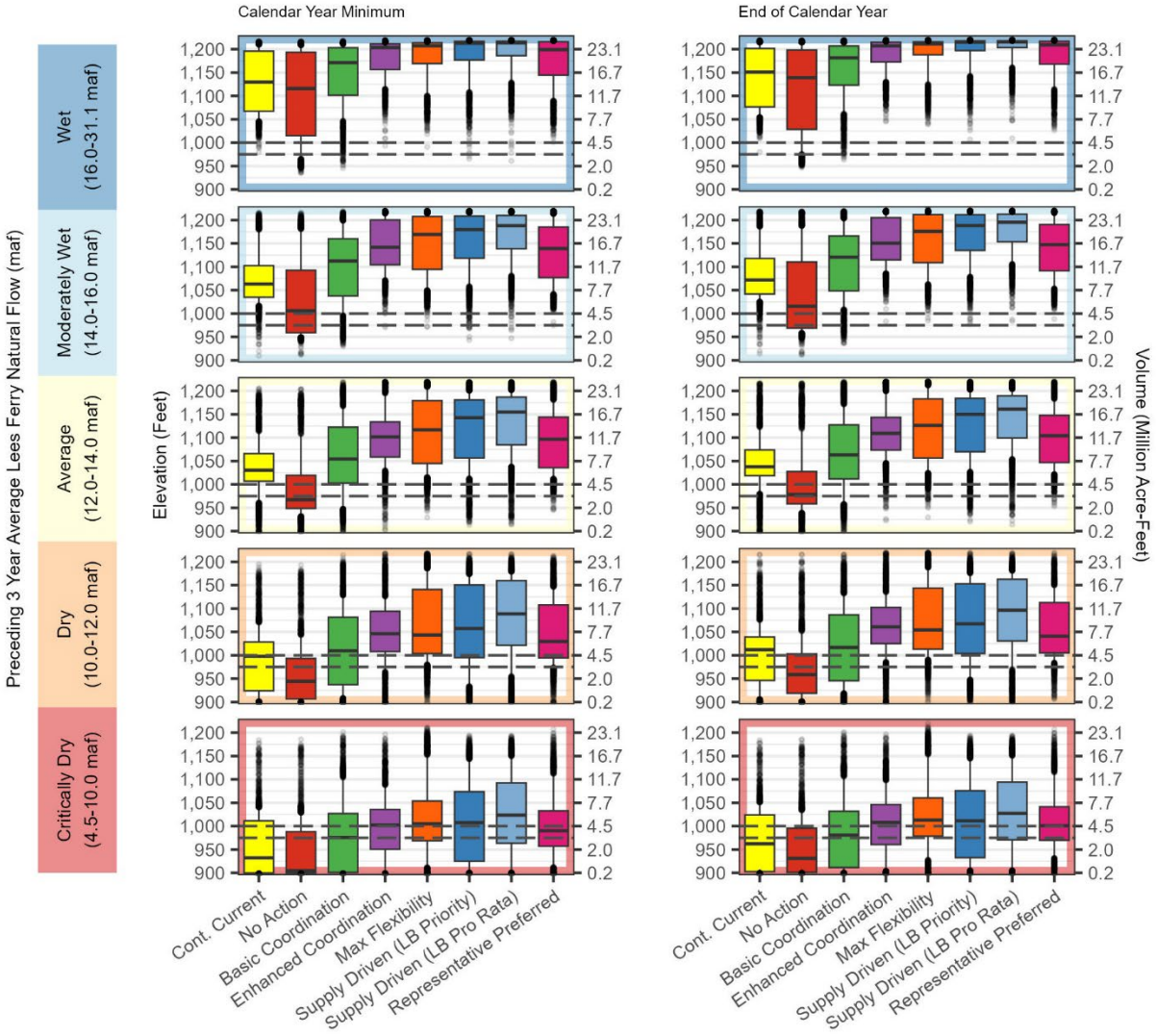
Refer to **Table TA 3-5** in **TA 3**, Hydrologic Resources, for a list of critical elevations at Lake Mead. A statistical breakdown of CRSS modeling results for end of calendar year (EOCY) elevations and minimum CY elevations at Lake Mead can be found in **Table TA 3-6** and **Table TA 3-7** in **TA 3**, Hydrologic Resources, respectively.

Figure 3-10 below looks at the response of Lake Mead CY minimum elevations, and EOCY elevations and storage volumes to different hydrologic conditions under different alternatives by looking at the preceding three-year average of Lees Ferry natural flow. The figure visualizes the same data that is included in **Table TA 3-6** and **Table TA 3-7** in two side by side conditional box plot panels. In each flow category shown in the box plots, the key elevations of 1,000 feet and 975 feet are identified with dashed lines. These elevations are important because they provide a 50-foot and a 25-foot buffer from 950 feet—the elevation below which water can only be released through the intake towers, constraining both the volume of water able to be released as well as the ability to generate power. Lake Mead requires larger buffers above the hydropower and critical infrastructure elevations than Lake Powell because Reclamation is required to deliver water orders that have already been approved. As a result, there is generally less flexibility to adjust releases from Hoover Dam than from Glen Canyon Dam.

Under the Average Flow Category, the No Action Alternative already performs poorly, with a median EOCY elevation of just 978 feet, which is between the two critical thresholds, while all action alternatives maintain medians above 1,000 feet. Under the Critically Dry Flow Category, the No Action Alternative and CCS Comparative Baseline fall to medians of 931 and 962 feet respectively, well below both thresholds, while the Enhanced Coordination, Maximum Operational Flexibility, and Supply

Driven (both LB Priority and LB Pro Rata approaches) Alternatives maintain medians above 1,000 feet. The Representative Preferred Alternative achieves a median EOCY elevation of 1,041 feet under the Dry Flow Category and 1,001 feet under the Critically Dry Flow Category, remaining above 975 feet in close to 75 percent of Critically Dry Flow Category years.

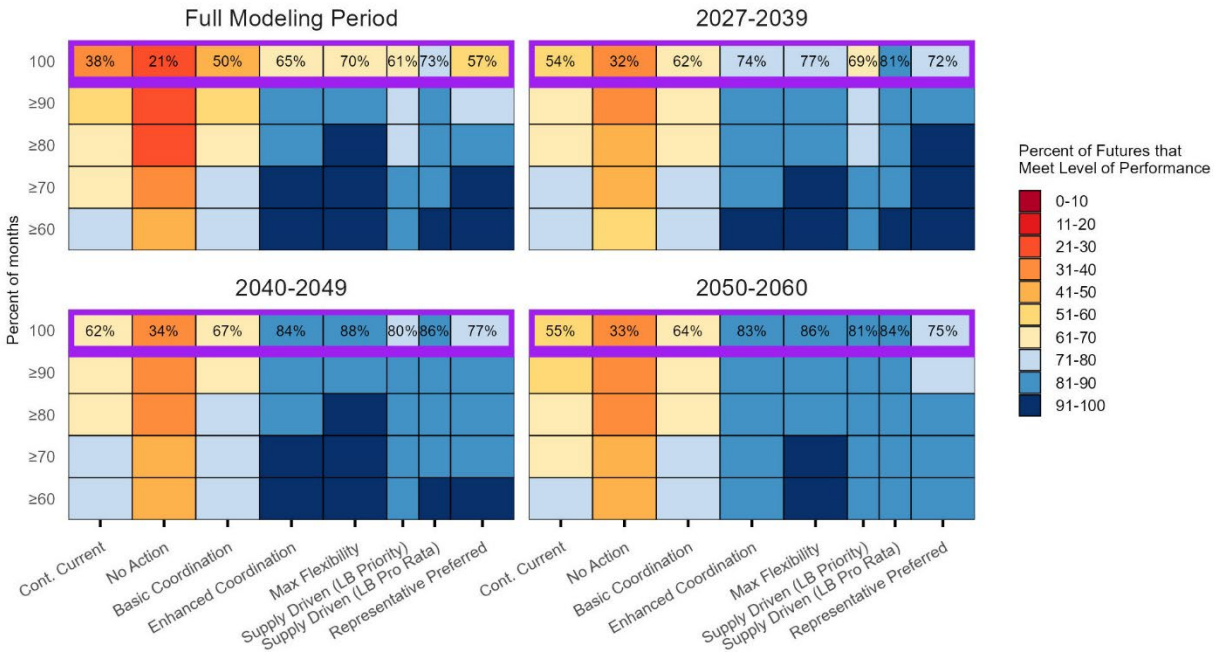
Figure 3-10
CY Minimum and EOCY Elevations and Storage Volumes of Lake Mead



The CY minimum elevations panel follows the same pattern as the EOCY elevations panel, but some median elevations are slightly lower.

Figure 3-11 compares alternatives with respect to keeping Lake Mead above elevation 975 feet in 100 percent of months. This critical threshold is important because it provides a 25-foot buffer to protect critical infrastructure and hydropower, which can no longer be produced at elevation 950 feet.

Figure 3-11
Lake Mead 975 Feet: Robustness.
Percent of futures in which Lake Mead elevation stays above 975 feet in the percent of months specified by each row



For the 975-foot robustness metric over the Full Modeling Period, the Maximum Operational Flexibility and Supply Driven (LB Pro Rata approach) Alternatives lead, meeting the preferred minimum performance in 70 percent and 73 percent of futures respectively, the Representative Preferred Alternative achieves the preferred minimum performance in 57 percent of futures over the Full Modeling Period (72 percent in the first decade), and the No Action Alternative performs worst meeting the preferred minimum performance in only 21 percent of futures.

Lake Mohave and Lake Havasu Elevations

Lake Mohave and Lake Havasu are operated under existing rule curves that determine specific target elevations at the end of each month. The existing rule curves were used in CRSS and applied to operations for all alternatives and the CCS Comparative Baseline. As such, water surface elevations at Lake Mohave and Lake Havasu are not affected.

Conservation Activity

Conservation activity modestly improves reservoir elevations for most action alternatives. For the Representative Preferred Alternative, enabling conservation raises median Lake Powell EOWY elevations by approximately 1.2 feet under the Dry Flow Category and 0.8 feet under the Critically Dry Flow Category. The effect is more pronounced at Lake Mead, where conservation raises the median EOCY elevation by 11.8 feet under the Dry Flow Category and 5.6 feet under the Critically Dry Flow Category.

Issue 2: System Storage

System storage is anticipated to be affected by the various alternatives as the result of changes to operational activities. The impacts on various combinations of system storage are summarized below. Refer to **Section TA 3.2.2**, Issue 2: System Storage, in **TA 3**, Hydrologic Resources, for details regarding impacts.

Combined system storage is evaluated across three reservoir groupings, each providing a different perspective on overall system conditions. Across all three groupings, storage declines with drying hydrology and the ranking of alternatives is generally consistent, with the Maximum Operational Flexibility and Enhanced Coordination Alternatives consistently producing the highest combined storage and the No Action Alternative producing the lowest.

Combined System Storage at Lake Powell and Lake Mead

Analysis of the combined storage across Lake Powell and Lake Mead helps to understand the overall condition of the Colorado River system. Based on this analysis, the primary drivers of Colorado River system conditions are related to assumptions for shortage operations and conservation activities. Refer to **Table TA 3-11** in **TA 3**, Hydrologic Resources, for a statistical breakdown of CRSS modeling results for EOWY combined system storage at Lake Powell and Lake Mead as a percentage of the total storage capacity. Refer to **Figure TA 3-18** in **TA 3** for the box plot representation of the combined system storage of Lake Powell and Lake Mead.

The combined live storage capacity of Lake Powell and Lake Mead is 49.43 maf. Under the Average Flow Category, the Maximum Operational Flexibility and Enhanced Coordination Alternatives maintain median combined storage above 50 percent of total capacity, while the No Action Alternative has the lowest median storage (27 percent) with nearly half of modeled years falling below the September 2022 historic low of 26.55 percent full.

Under the Critically Dry Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have median combined storages near the lowest observed EOWY storage reference of 26.55 percent, while under the CCS Comparative Baseline and No Action and Basic Coordination Alternatives, more than 75 percent of modeled years are below the 2022 historic low.

The Representative Preferred Alternative ranks fifth among alternatives, maintaining a median combined storage of 32 percent under the Dry Flow Category and 21 percent under the Critically Dry Flow Category, with roughly 75 percent of years in the Critically Dry Flow Category falling below the 2022 historic low.

Combined System Storage at CRSP Reservoirs

Analysis of the combined storage across CRSP reservoirs helps to understand the overall status of Lake Powell and the CRSP Upper Initial Units (Flaming Gorge, Navajo, and Blue Mesa reservoirs). Lake Powell makes up approximately 80 percent of the total CRSP storage capacity, so trends in combined storage capacity are primarily controlled by Lake Powell operations. The CRSP Upper Initial Unit reservoirs can be operated (within their RODs) so that releases help bolster elevations in Lake Powell and protect Glen Canyon Dam infrastructure. Refer to **Table TA 3-12** in **TA 3** for a statistical breakdown of CRSS modeling results for EOWY combined system storage at CRSP reservoirs as a percentage of the total storage capacity. Refer to **Figure TA 3-19** in **TA 3** for the box plot representation of the combined system storage at CRSP reservoirs.

Because the Upper Initial Unit reservoirs vary minimally across alternatives, CRSP median combined storage trends closely mirror Lake Powell elevation performance described in **Issue 1**. Under the Average Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives lead with median combined storage of 63 and 62 percent of capacity respectively, while other alternatives cluster near 50 percent. Under the Critically Dry Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain the highest median combined storage at 41 and 38 percent respectively, while remaining alternatives fall to 21-26 percent.

The Representative Preferred Alternative ranks third overall with a median combined storage of 37 percent under the Dry Flow Category and 27 percent under the Critically Dry Flow Category.

Combined System Storage at Seven Reservoirs

Analysis of the seven-reservoir system storage (CRSP Upper Initial Units of Flaming Gorge, Navajo, and Blue Mesa Reservoirs, as well as Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu) volumes over time can be used to better understand overall system conditions. Refer to **Table TA 3-13** in **TA 3** for a statistical breakdown of CRSS modeling results for EOWY combined system storage of the seven reservoirs as a percentage of the total storage capacity. Refer to **Figure TA 3-20** in **TA-3** for the box plot representation of the combined system storage of the seven reservoirs.

Under the Average Flow Category, the Maximum Operational Flexibility Alternative has the highest median combined storage (60 percent), followed by the Enhanced Coordination Alternative at 59 percent, while the No Action Alternative (35 percent) and the CCS Comparative Baseline (38 percent) have the lowest median combined storages.

The Representative Preferred Alternative achieves median combined storage of 37 percent under the Dry Flow Category and 27 percent under the Critically Dry Flow Category, ranking fifth among all alternatives which is consistent with its ranking in the Powell-Mead and CRSP groupings.

Issue 3: Reservoir Releases

Releases from reservoirs are anticipated to be affected by the various alternatives as the result of changes to operational activities. The impacts on reservoir releases are summarized below. Refer to **Section TA 3.2.3**, Issue 3: Reservoir Releases, **TA 3**, Hydrologic Resources, for details regarding impacts on reservoir releases.

Glen Canyon Dam (Lake Powell) Releases

Generally, alternatives that prioritize higher elevations in Lake Powell result in lower median annual releases from Glen Canyon Dam. This trend demonstrates the tradeoffs between maintaining reservoir elevations to protect critical infrastructure and annual releases from reservoirs. Refer to **Table TA 3-14** in **TA 3** for a statistical breakdown of CRSS modeling results for EOWY releases from Glen Canyon Dam. Refer to **Figure TA 3-21** in **TA 3** for the box plot representation of the EOWY releases from Glen Canyon Dam. In addition to annual releases, 10-year releases from Glen Canyon Dam are also considered. Refer to **Table TA 3-15** and **Figure TA 3-22** in **TA 3** for modeled results for the 10-year Glen Canyon Dam releases.

Under the Average Flow Category, median annual releases cluster near 8.23 maf for most alternatives. Under the Critically Dry Flow Category, releases diverge significantly: the No Action Alternative and

CCS Baseline release the most (6.36 and 6.41 maf respectively) partly due to infrastructure-constrained variability below 3,490 feet, while the Enhanced Coordination Alternative releases the least (5.11 maf).

The Representative Preferred Alternative has a median annual release of 7.20 maf under the Dry Flow Category and 6.0 maf under the Critically Dry Flow Category and has the least variability in Glen Canyon Dam releases under Critically Dry conditions.

At the Lee Ferry Compact Point median 10-year cumulative flows are highest under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) (84.6 maf), followed by the No Action Alternative (83.6 maf) and the CCS Comparative Baseline (83.3 maf), with the Enhanced Coordination Alternative having the lowest cumulative flows (81.3 maf).

The Representative Preferred Alternative achieves a median 10-year flow of 76.4 maf under the Dry Flow Category, exceeding the 75.0 maf threshold in over 50 percent of Dry Flow Category years, but surpassing the 82.5 maf threshold in fewer than 25 percent of Dry Flow Category years.

Hoover Dam (Lake Mead) Releases

Generally, alternatives with higher Lake Mead elevations correspond to lower releases from Hoover Dam, especially in the Average Flow Category (12.0–14.0 maf). However, the range of interquartile variability for releases from Hoover Dam is wide, especially in the Wet Flow Category (16.0–31.11 maf) and the Critically Dry Flow Category (4.46–10.0 maf), indicating more variability in releases as flow conditions get more extreme (in both directions). Refer to **Table TA 3-17** in **TA 3** for a statistical breakdown of CRSS modeling results for EOCY releases from Hoover Dam. Refer to **Figure TA 3-24** in **TA 3** for the box plot representation of the EOCY releases from Hoover Dam.

Under the Average Flow Category, the No Action Alternative releases the most from Hoover Dam (median of 8.63 maf), while Enhanced Coordination releases the least (7.58 maf). In the Critically Dry Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have the lowest median releases (6.48 and 6.40 maf respectively). All alternatives except the Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have more variability under Critically Dry than Average conditions.

The Representative Preferred Alternative falls near the middle across all flow categories, with Hoover Dam median releases of 7.61 maf under the Dry Flow Category and 6.94 maf under the Critically Dry Flow Category and average variability compared to other alternatives.

Davis Dam (Lake Mohave), Parker Dam (Lake Havasu) Releases, and Morelos Diversion Dam

Releases from Davis Dam and Parker Dam are based on target elevations defined by the existing rule curves. Inflows into Lake Mohave vary across alternatives, so releases from Davis Dam and Parker Dam subsequently vary across alternatives to maintain target elevation ranges. These releases follow similar trends to Hoover Dam releases

Issue 4: River Flows

River flows throughout the seven analyzed reaches of the Colorado River, from Glen Canyon Dam to the SIB, largely reflect upstream reservoir releases, with tributary contributions and return flows accounting for only a small fraction of total flow. All alternatives show declining median flows with

drier hydrology across all reaches. Refer to **Section TA 3.2.4**, Issue 4: River Flows, in **TA 3**, Hydrologic Resources, for details regarding impacts on river flows within specific reaches of the Colorado River.

Downstream of Glen Canyon Dam

Reach 1 of the river extends 292 miles from Glen Canyon Dam, through GCNP, to Lake Mead. Flows in this reach are dominated by releases from Lake Powell plus smaller inflows from the Paria and Little Colorado rivers (3 percent of total flow).

Annual flow patterns in this reach generally follow the Glen Canyon Dam release patterns summarized in Issue 3. Tributary inflows are modeled identically across all alternatives. The Representative Preferred Alternative produces median Water Year releases of 8.23 maf under the Average Flow Category, consistent with the No Action and the Basic Coordination Alternatives, and the CCS Comparative Baseline, and 6.0 maf under the Critically Dry Flow Category; it is the least variable of any alternative under the driest conditions.

Downstream of Hoover Dam to Imperial Dam (Reaches 2–5)

Reaches 2 through 5 are primarily influenced by releases from Hoover, Davis, and Parker Dams, with additional localized effects from one major tributary (Bill Williams River), diversions, and return flows.

Flows through these reaches are driven almost entirely by upstream dam releases, declining progressively with drying hydrology across all alternatives. The Enhanced Coordination Alternative consistently produces the lowest median flows while the No Action and Basic Coordination Alternatives produce the highest flows under dry conditions. The Representative Preferred Alternative performs near the middle of all alternatives throughout these reaches, with median annual flows of 7.89 maf below Hoover Dam, 7.8 maf below Davis Dam, 6.2 maf below Parker Dam, and 5.3 maf at Imperial Dam under the Dry Flow Category, declining to 6.94, 6.9, 5.9, and 5.0 maf respectively under the Critically Dry Flow Category.

Downstream of Imperial Dam (Reaches 6–7)

Below Imperial Dam, flows are primarily driven by delivery requirements and remain relatively stable across alternatives, ranging from 0.8 to 1.1 maf median under most flow categories. Below the Morelos Diversion Dam in the limitrophe, flows are infrequent across all alternatives, occurring in fewer than 10 percent of years under the Average, Dry, and Critically Dry Flow Categories. The Representative Preferred Alternative produces median flows of approximately 0.9 maf below Imperial Dam across both the Dry and Critically Dry Flow Categories, which is on the low end compared to other alternatives, and sees flows in the limitrophe in greater than 25 percent of years only under the Wet Flow Category.

Issue 5: Groundwater

Groundwater elevations adjacent to reservoirs and within specific reaches along the Colorado River may be affected by the various alternatives, depending on the hydraulic connectivity and geotechnical characteristics of the area. In reaches of the Colorado River that have a direct connection to groundwater, changes in river flows and changes in reservoir elevations are anticipated to affect groundwater elevations. The reaches that are anticipated to have impacts on groundwater as the result of changes to operational activities are summarized below. Refer to **Section TA 3.2.5**, Issue 5:

Groundwater, in **TA 3**, Hydrologic Resources, for details regarding impacts on groundwater within specific reaches of the Colorado River.

Reaches Anticipated to Have Impacts

Adjacent to Lake Powell, groundwater elevations are expected to track reservoir pool elevations. The Representative Preferred is third most robust at maintaining Lake Powell elevations above critical thresholds yielding adjacent groundwater elevations lower than the Enhanced Coordination and Maximum Operational Flexibility Alternative and comparable to the CCS Comparative Baseline and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). The No Action Alternative is least robust at maintaining Lake Powell elevations and is therefore expected to result in the lowest adjacent groundwater elevations.

Reaches 3 through 5 of the Colorado River are made up of alluvial fill groundwater basins and impacts on groundwater elevations mirror trends seen for river flows in Issue 4, where higher flows result in higher groundwater elevations. Under the Dry and Critically Dry Flow Categories, the Basic Coordination Alternative produces the highest flows in these reaches and is therefore expected to yield the highest groundwater elevations. The Representative Preferred Alternative falls near the middle of all alternatives and is likely to result in groundwater elevations that are higher than the Enhanced Coordination and Supply Driven Alternative (LB Pro Rata approach) but lower than the Basic Coordination, and Supply Driven (LB Priority approach) Alternatives, and the CCS Comparative Baseline in the Critically Dry Flow Category. The Enhanced Coordination Alternative is anticipated to result in the lowest groundwater elevations in these reaches due to its consistently lower river flows.

The downstream portion of Reach 7 is considered a losing reach where the river recharges groundwater. Groundwater elevations are likely to continue to decline under dry conditions.

Reaches Not Anticipated to Have Impacts

Reaches of the Colorado River that contain bedrock, that consist of lined canals, or which otherwise have limited hydraulic connectivity to groundwater are not anticipated to have impacts on groundwater associated with changes to operational activities. These portions of the analysis area include the Grand Canyon, Lake Mead, Reach 2 within the Black Canyon, and Reach 6 which diverts Colorado River water into lined canals. Likewise, reservoirs that maintain the same water surface elevation regardless of alternative are not anticipated to affect groundwater levels. These reservoirs include Lake Mohave and Lake Havasu, which will continue to be operated under their existing release rule curves, which keeps reservoir elevations within a tight range. The upstream portion of Reach 7 has high groundwater elevations from nearby irrigated fields, and the alternatives are not anticipated to impact groundwater elevations in this reach.

Summary Comparison of Alternatives

Beginning with reservoir elevations, performance differences among alternatives increase under drier conditions. The Representative Preferred Alternative meets the preferred minimum performance in 40 to 50 percent of futures over the Full Modeling Period and 52 to 58 percent in the first decade for Lake Powell, and 57 to 63 percent of futures over the Full Modeling Period and 62 to 72 percent in the first decade for Lake Mead. Absent additional action, the Representative Preferred Alternative is reasonably likely to be vulnerable to elevations below key thresholds within the next 10 years.

System storage declines under drier conditions across all alternatives and reservoir groupings, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives generally maintaining the highest median storage. Under the Representative Preferred Alternative, median combined storage in the Dry Flow Category is 32 percent for Powell-Mead, 37 percent for CRSP, and 37 percent for the seven-reservoir system, declining to 21, 27, and 27 percent respectively in the Critically Dry Flow Category. More than 25 percent of Dry Flow Category years and nearly 75 percent of Critically Dry Flow Category years fall below the lowest observed historical Powell-Mead combined storage.

Alternatives that prioritize higher reservoir elevations generally release less water, demonstrating the operational tradeoff between maintaining reservoir elevations to protect critical infrastructure and annual releases from reservoirs. Releases generally decrease under drier conditions, with greater variability for most alternatives. Under the Representative Preferred Alternative, median Glen Canyon Dam releases decline from 7.20 maf in the Dry Flow Category to 6.0 maf in the Critically Dry Flow Category, remaining the least variable among alternatives under the Critically Dry Flow Category. At the Lee Ferry Compact Point, median 10-year volumes are 76.4 maf under the Dry Flow Category and 73.9 maf under the Critically Dry Flow Category. Releases under the Representative Preferred Alternative from Hoover, Davis, and Parker Dams are generally in the middle range of alternatives, decreasing as conditions dry.

For most reaches of the Colorado River, flows mostly comprise releases from upstream reservoirs and overall trends for river flows mirror those seen for reservoir releases. Inflows from perennial tributaries are minor and do not change between alternatives. River flows generally decrease with drying hydrology across all reaches and alternatives. Under the Representative Preferred Alternative, annual flow volumes are generally in the middle of the range of alternatives below Hoover and Davis Dams, and similar to most alternatives below Parker Dam. At Imperial Dam, median annual flow is 5.3 maf in the Dry Flow Category and 5.0 maf in the Critically Dry Flow Category. Below Imperial Dam, median annual flow is 0.9 maf in both categories, on the low end of all alternatives. Flows below Morelos Diversion Dam are infrequent across all alternatives in the Average, Dry, and Critically Dry Flow Categories.

Groundwater effects are qualitative, complex, and most likely near Lake Powell and in alluvial river reaches with hydraulic connectivity. Under the Representative Preferred Alternative, groundwater elevations near Lake Powell are anticipated to be lower than under the Maximum Operational Flexibility and Enhanced Coordination Alternatives but higher than under the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata) Alternatives. Across river reaches, the Representative Preferred Alternative is generally not identified as producing either the highest or lowest anticipated groundwater elevations where flow-related effects are possible.

3.4 Water Deliveries

3.4.1 Affected Environment

Water from the Colorado River is delivered to entities in the Lower Division States and Mexico for domestic and agricultural use, in accordance with the Law of the River. Colorado River water is also used to serve many purposes in the Upper Basin. The geographic scope of this EIS does not extend

above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users. With respect to Upper Basin conservation, the nexus to the proposed federal action is the storage and delivery of that conserved water in Lake Powell. The effects of this storage in and delivery from Lake Powell are within the scope of the EIS (see **Section 3.3**, Hydrologic Resources, and **TA 3**, Hydrologic Resources), while specific activities that may be undertaken in the Upper Basin to generate the conserved water are not within the scope of this EIS. Any such activities are unknown at this time and will not necessarily require federal decision making. Any federal decisions associated with these conservation activities will be assessed outside of this EIS.

Legal and Policy Framework

The Law of the River is an umbrella term for the collection of laws, compacts, decrees, court decisions, contracts, and regulatory guidelines that govern management and operation of the Colorado River. Notable documents that define the Law of the River are identified and further explained in **TA-4**, Water Deliveries.

Apportionments

The Colorado River Compact apportions 7.5 million acre-feet (maf) of water per year to the Upper Colorado River Basin (Upper Basin), and 7.5 maf to the Lower Basin with division of the two basins occurring at Lee Ferry, Arizona. Water is distributed among the Upper Division States by the 1948 Upper Colorado River Basin Compact as a percentage of the total amount available for consumptive use each year after the deduction of Arizona's 50 thousand acre-feet (kaf) apportionment of Upper Basin water. The water is distributed among Colorado (51.75 percent), Utah (23 percent), Wyoming (14 percent), and New Mexico (11.25 percent). The Upper Division State apportionments have not yet been fully developed. Water apportionments to the Lower Division States total 7.5 maf for consumptive use, subject to annual increases or reductions pursuant to Secretarial determinations of a Surplus or a Shortage condition. Lower Division State apportionments are set by the BCPA as follows: California (4.4 maf), Arizona (2.8 maf), and Nevada (0.3 maf). See **Section 1.8** for a description of historical water use across the Upper and Lower Basins.

Rights to use Colorado River water within the Lower Division States, known as entitlements, are established in accordance with the BCPA and the Consolidated Decree. All of the water apportioned to the Lower Division States is allocated in accordance with these documents. For users in the Lower Division States, entitlements arise through (i) a decreed right, (ii) a Section 5 water delivery contract, or (iii) a Secretarial reservation. According to Section 5 of the BCPA, the Secretary is authorized as the contracting authority for the Lower Colorado River, and any user of Colorado River water in the Lower Basin is required to have a contract with the Secretary acting through the Bureau of Reclamation. The Consolidated Decree lists and quantifies all PPRs in the Lower Division States. PPRs are the highest priority Lower Basin mainstream Colorado River water entitlements that were perfected before June 25, 1929. The Consolidated Decree also lists federal reserved water rights for five Indian reservations. PPRs are satisfied first in order of priority in years when less than 7.5 maf of water is available from the Colorado River for consumptive use in the Lower Division States before other entitlements are fulfilled.

Storage & Delivery of Conserved and Non-System Water and Treatment of Pre-2027 Intentionally Created Surplus

As outlined in the 2007 Interim Guidelines, Lower Basin entitlement holders can store conserved water in Lake Mead, provided they have an ICS exhibit and an approved ICS creation plan. ICS may only be created in a given year via approved conservation actions and a reduction in consumptive use. Beginning in 2027, guidelines regarding the delivery and creation of ICS will change in accordance with the 2007 ROD and Lower Basin DCP to incorporate additional thresholds and repayment timelines. Additional information is available in **TA-4**, Water Deliveries.

Lower Basin Water Supply Determination

Annually, the Secretary determines the water supply condition for the Lower Division as Normal, Surplus, or Shortage Condition based on Lake Mead's projected elevation on January 1, as modeled by the prior year's August 24-Month Study. The 2007 ROD provides objective criteria used to make annual water supply determinations. The guidance provides supply thresholds under which consumptive use from Lake Mead would be Normal, Surplus, or Shortage Condition, and outlines coordinated reservoir management strategies between Lake Powell and Lake Mead. From 2008 to 2021, Lake Mead operated under Normal/ICS Surplus Conditions, shifting to Shortage Conditions from 2022 through 2025. Further historical information is available in **TA-4**, Water Deliveries.

Mexico's Allotment

Mexico's allotment of Colorado River water is described under Article 10 of the 1944 Water Treaty. The 1944 Water Treaty guarantees that 1.5 maf will be delivered to Mexico annually. Additionally, it outlines Surplus Conditions such that no greater than 1.7 maf shall be delivered to Mexico in a given year, and Extraordinary Drought such that deliveries are reduced in proportion to reductions of U.S. consumptive uses. Minute 242 provides guidance for the geographic locations where deliveries from the U.S. will be made. Minute 323 adjusts how and under what conditions deliveries occur but does not change Mexico's allotment. For further information regarding Mexico's allotment and pertinent policy, refer to **Appendix N**, International Border Region of the Colorado River.

Distribution of Shortages and Reductions to and within the Lower Division States

The 2007 Interim Guidelines, the 2019 DCP and Minute 323 to the 1944 Water Treaty provide for a maximum of 1.375 maf of shortages and reductions (including DCP Contributions and BWSCP savings). Beyond these required activities, Reservoir Protection Conservation implemented through the 2024 ROD resulted in additional Lower Basin conservation from 2023 to 2026. The Reservoir Protection Conservation may vary year to year but is designed to achieve a collective total volume of 3.0 maf. A summary of the 2007 Interim Guidelines Shortages, 2019 DCP contributions, and 2024 ROD conservation is shown in **Table TA-4-6** in **TA-4**, Water Deliveries.

Apportionment is allocated for Arizona, California, and Nevada as outlined in **Tables TA-4-7** through **TA-4-9** in **TA-4**, Water Deliveries.

3.4.2 Environmental Consequences

Methodology

Reclamation uses CRSS for long-term planning studies. CRSS simulates Basin conditions decades into the future (the full analysis period is through 2060) and can be used to account for hydrologic uncertainty. Refer to **Appendix A**, CRSS Model Documentation for more details related to model documentation. For background and guidance related to figures used in the full analysis, see **Section 3.2**, Analysis Methods. Additionally, the SAMs and ADMs were used to analyze potential impacts of the alternatives on individual water users within each Lower Division State under varying levels of shortage. Modeling assumptions for the SAMs and ADMs are summarized in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation.

Reclamation uses CRSS for long-term planning studies. CRSS simulates Basin conditions decades into the future (the full analysis period is through 2060) and can be used to account for hydrologic uncertainty. Refer to **Appendix A**, CRSS Model Documentation for more details related to model documentation. Additionally, the SAMs and ADMs were used to analyze potential impacts to individual water users within each Lower Division State under varying levels of shortage. Modeling assumptions are summarized in **Appendix C**, and additional details on the DMDU framework and figure interpretation are provided in **Appendix E** and **Section 3.2.6**.

Impact Analysis Area

The geographic scope of the water deliveries analysis is the Colorado River corridor from the upstream limit of full pool elevation of Lake Powell to the downstream limit of the Southerly International Boundary. The geographic scope of this EIS does not extend above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users. Although assumptions about Upper Basin conservation are included in various alternatives, no assumptions are made with respect to where conserved water is generated nor about the specific activities that produce it (see **Appendix B** for more information).

Assumptions

CRSS was used to analyze shortage volumes and Lower Basin water deliveries, and the SAMs and ADMs were used to analyze shortage impacts to specific groups of water users. CRSS also includes assumptions regarding Upper Basin conservation activities but does not make assumptions with respect to conservation by different entities or via specific activities. Refer to their respective appendices for more details related to model assumptions and documentation. All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (see **Appendix S**, Additional Description of Alternatives). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

Impact Indicators

The following indicators were used to assess impacts on water deliveries due to operational activities: magnitude of shortage volumes, distribution of shortages, and depletions among and within the Lower Division States.

Issue 1: Apportionments to the Upper Division States

The alternatives would not affect apportionments to the Upper Division States. Therefore, no impact analysis is warranted.

Issue 2: Lower Division States Apportionments and Water Entitlements

The approaches to distributing shortages incorporated in all alternatives are designed to explore a wide range of potential concepts and impacts; they do not reflect an intention by Reclamation to alter apportionments or water entitlements. However, because the concepts would affect a range of users, impacts on deliveries to different entities are analyzed in Issues 3, 5, and 7, and addressed in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation. Once an alternative is selected, the Department will supplement the analysis if necessary.

Issue 3: Lower Division States Water Supply Determinations and Total Water Deliveries

Issue 3 addresses how operational activities affect water deliveries for the Lower Division States and Mexico. This is analyzed through the following key metrics: shortage versus dead pool–related reductions, conservation modeling assumption effects, shortage, annual depletions, and surplus.

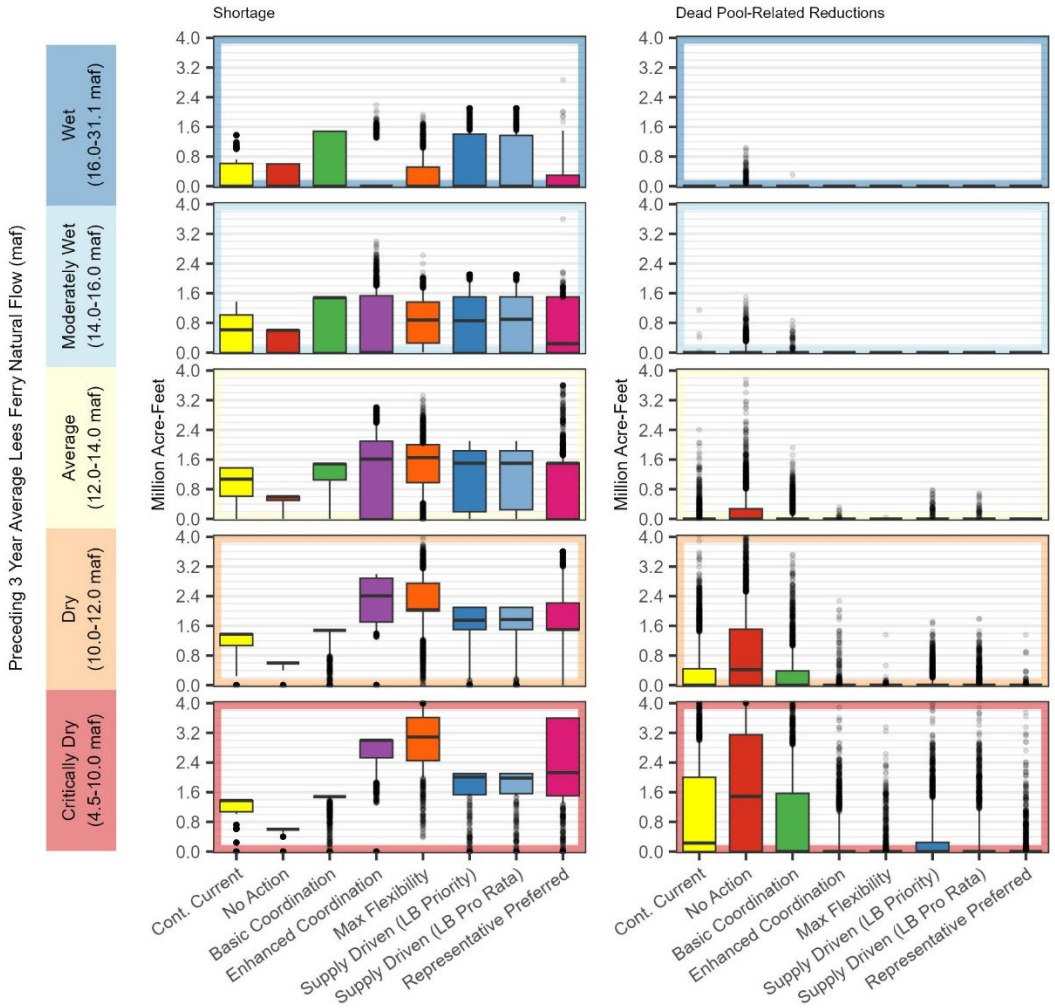
Shortage versus Dead Pool–Related Reductions: Comparison for Full Lower Basin

Shortage refers to delivery reductions at the Basin, state, or individual apportionment level that are defined and distributed as part of an alternative's shortage operations. Volumes and distributions of shortage are described in **Chapter 2**. Dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. In some cases, these unplanned reductions occur because Lake Mead is approaching dead pool (elevation 895 feet) and in some cases they occur higher (up to elevation 950 feet).

Annual Lower Basin Reductions

Figure 3-12 compares modeled annual Lower Basin shortages and dead pool-related reductions across alternatives and flow categories, including modeling assumptions for reductions in deliveries to Mexico. Overall, alternatives with lower maximum shortage volumes tend to have more frequent or larger dead pool-related reductions, most notably the No Action Alternative. Under the Average Flow Category, median shortages are 2.1 maf or less. The Maximum Operational Flexibility and Enhanced Coordination Alternatives have the highest median shortages at 1.7 and 1.6 maf, while the CCS Comparative Baseline and No Action Alternative are lower at 1.1 and 0.6 maf. Dead pool-related reductions are generally infrequent for action alternatives under the Average Flow Category, except under the Basic Coordination Alternative, while the No Action Alternative has the most frequent and highest-magnitude reductions. Differences are greatest under the Critically Dry Flow Category, where most action alternatives have higher median shortages but lower dead pool-related reductions than the CCS Comparative Baseline and No Action Alternative. For the Representative Preferred Alternative, the Dry Flow Category shows a median shortage of 1.5 maf, median dead pool-related reductions of 0.0 maf, and dead pool-related reductions only in outlier years. Under the Critically Dry Flow Category, its median shortage is 2.1 maf, median dead pool-related reductions remain 0.0 maf, and 10 percent of years have dead pool-related reductions.

Figure 3-12
Annual Lower Basin Reductions



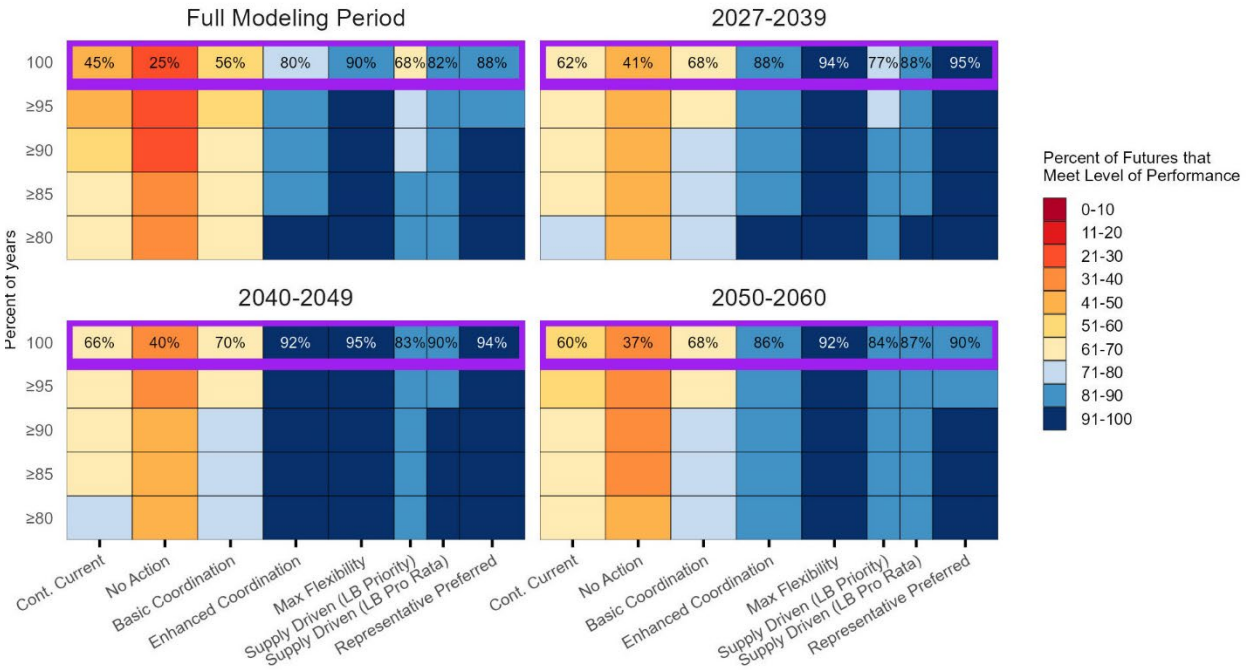
Note: Shortage and dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Lake Mead Dead Pool-Related Reductions

Figure 3-13 compares the robustness of each alternative in avoiding dead pool-related reductions at Lake Mead across the full modeling period and three subperiods. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative avoids dead pool-related reductions in 100 percent of years. Over the full modeling period, the Maximum Operational Flexibility Alternative is the most robust, avoiding dead pool-related reductions in 90 percent of futures, followed by the Representative Preferred Alternative at 88 percent, Supply Driven Alternative (LB Pro Rata approach) at 82 percent, and Enhanced Coordination Alternative at 80 percent. These alternatives perform better than the Basic Coordination Alternative,

CCS Comparative Baseline, and No Action Alternative, which avoid dead pool-related reductions in 56, 45, and 25 percent of futures, respectively. For 2027-2039, the Representative Preferred and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance in 95 and 94 percent of futures, respectively. The Representative Preferred Alternative performs among the best alternatives in both the full modeling period and the 2027-2039 period.

Figure 3-13
Lake Mead Dead Pool–Related Reductions: Robustness.
Percent of futures in which dead pool-related reductions are avoided in the percent of years specified by each row



Note: Dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The Lake Mead dead pool vulnerability analysis shows what flow conditions are likely to cause dead pool-related reductions from Lake Mead in any year. Undesirable performance is based on the highlighted row in **Figure 3-13**, above. The driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The No Action Alternative is vulnerable at 11.6 maf, which is near the driest observed 10-year average flow of 11.8 maf, while the Basic Coordination Alternative and the CCS Comparative Baseline are vulnerable at 10.4 and 10.9 maf, respectively. Other action alternatives are not likely vulnerable unless flows are much drier than observed conditions. The Representative Preferred Alternative is likely vulnerable at a 10-year average flow of 8.0 maf, a condition not observed and present in fewer than 10 percent of Drying with Variability Ensemble traces. Further information and detailed figures can be found in **Figure TA 4-3** in **TA-4**, Water Deliveries.

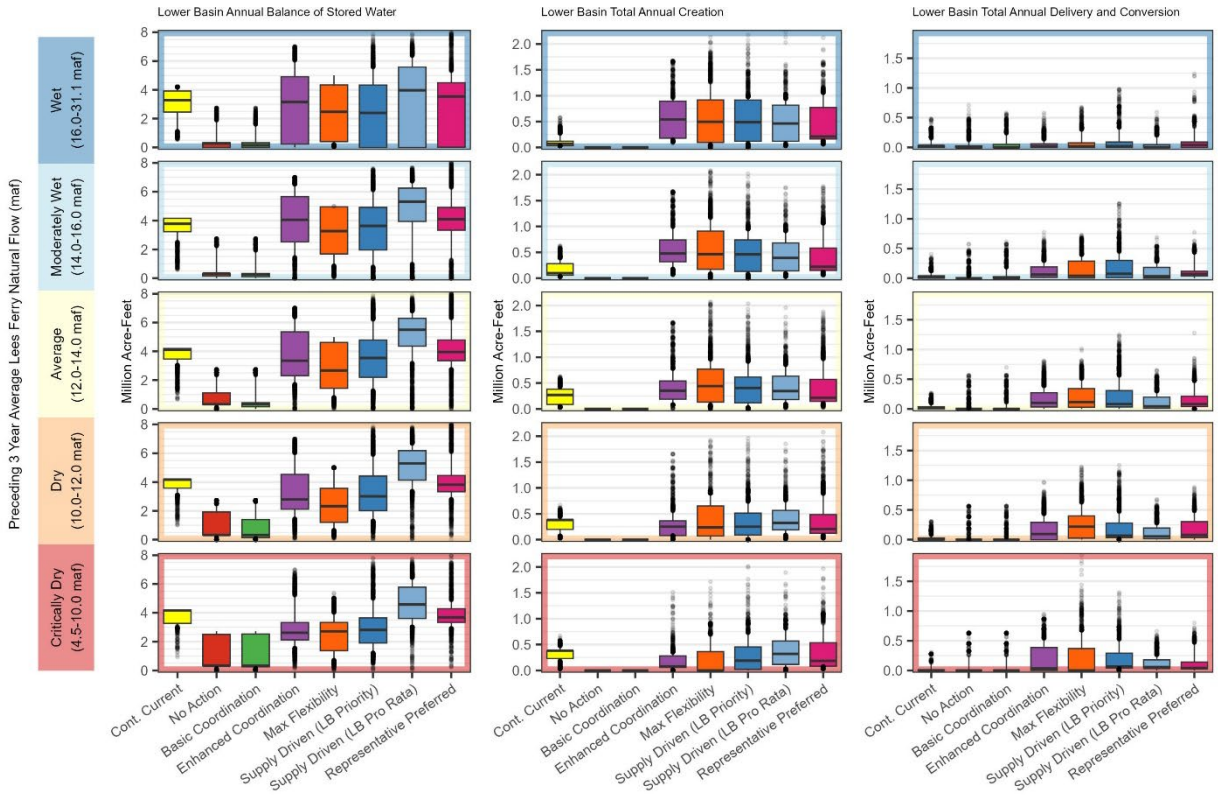
Conservation Activity

All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and Lake Mead. **Table TA 4-12** in **TA-4**, Water Deliveries summarizes the various conservation mechanisms for each action alternative.

Lower Basin Conservation Activity

Figure 3-14 shows Lower Basin conservation activity by alternative using conditional boxplots for stored water balance, annual conservation creation, and annual delivery and conversion. Stored water balances generally decline in the Dry and Critically Dry Flow Categories as annual creation decreases. Delivery and conversion volumes increase from the Average Flow Category to the Dry Flow Category, then stay the same or decrease in the Critically Dry Flow Category due to lower available stored water and/or low Lake Mead elevations. The No Action and Basic Coordination Alternatives have small balances because they do not include new conservation mechanisms. For the Representative Preferred Alternative, median stored water balances are 3.8 maf in the Dry Flow Category and 3.7 maf in the Critically Dry Flow Category. Median annual creation is 0.2 maf in both categories, while median delivery and conversion is 0.1 maf in the Dry Flow Category and 0.0 maf in the Critically Dry Flow Category.

Figure 3-14
Annual Lower Basin Conservation Activity



Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Effects of Modeling Assumptions for Total Basin Conservation Activity on Lower Basin Shortages and Deliveries

Modeling assumptions for conservation activity do not substantially affect median Lower Basin shortages or depletions, but they can influence variability across flow categories. These assumptions can also affect the frequency or magnitude of Lake Mead dead pool-related reductions, particularly in drier flow categories. Further information and detailed figures can be found in **TA-4**, Water Deliveries.

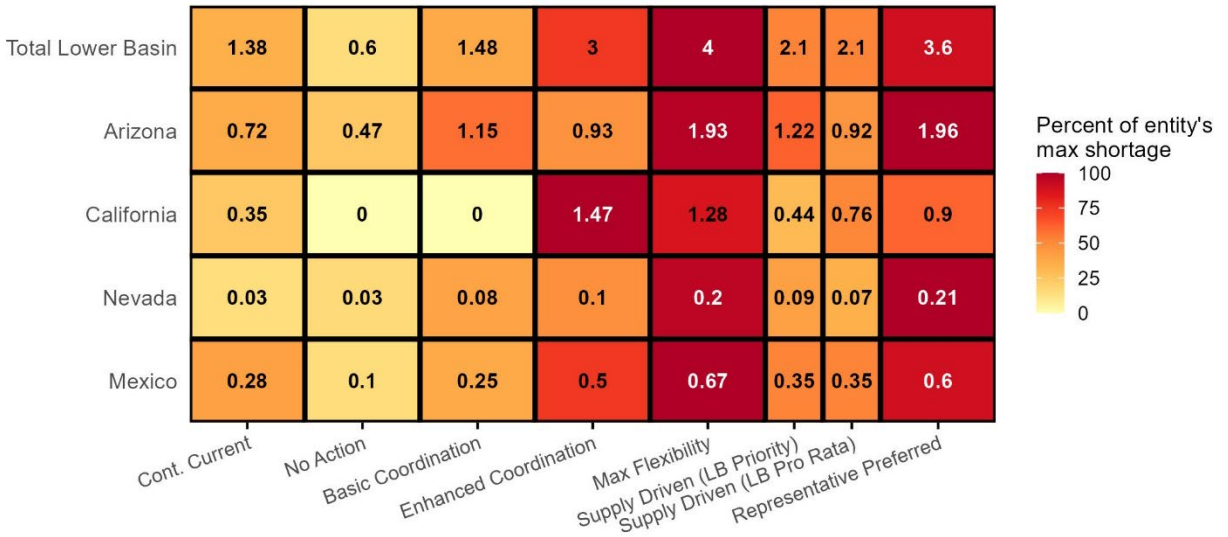
Shortage

This section compares all the alternatives and the CCS Comparative Baseline with respect to shortages to each of the Lower Division States and Mexico.

Maximum Shortage

Figure 3-15 compares maximum modeled shortages for the total Lower Basin and for each state and Mexico. Because the alternatives have different maximum volumes and also different distributions of shortage, each row has an independent color scale to facilitate identifying the maximum shortage to each entity. For all entities except California, either the Maximum Operational Flexibility Alternative or Representative Preferred Alternative produces the largest maximum shortage. The Enhanced Coordination Alternative produces California's largest maximum shortage due to its pro rata distribution and large total shortage volumes. The No Action Alternative produces the lowest, or tied-lowest, maximum shortage for all entities. Under the Representative Preferred Alternative, actual shortage distributions under specific operating guidelines may differ from the representative approach shown here.

Figure 3-15
Maximum Shortage (maf)



Note: Lower Basin shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage by State

Shortage under different hydrologic conditions categorized by the preceding 3-year average of Lees Ferry natural flow is compared across alternatives in **Figure 3-16**. There is a column for each Lower Division State and Mexico. The vertical axis for each state's column is scaled based on its respective volume of apportionment; the percent apportionment is shown on the left side of each column, and the absolute volume of shortage is shown on the right. A summary by state for Arizona, California, and Nevada follows.

Arizona

In Arizona, all alternatives impose shortages on Priority 4 users. Shortages to more senior users occur only under alternatives that use pro rata-based shortage distribution or when total Lower Basin shortages are large enough to extend beyond Priority 4 users. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives affect Priorities 1, 2 and 3 through pro rata-based distribution. The Maximum Operational Flexibility and Representative Preferred Alternatives affect Priority 2 and 3 users when shortages are large enough. Under the Representative Preferred Alternative, Priority 4 median shortages are 1,167.1 kaf in the Dry Flow Category and 1,442.6 kaf in the Critically Dry Flow Category. Priority 1 users do not take shortage. The sum of the shortages across priority groups is shown in **Figure 3-16**, below. Shortage is also displayed by priority in **Figure TA 4-11** in **TA-4**, Water Deliveries.

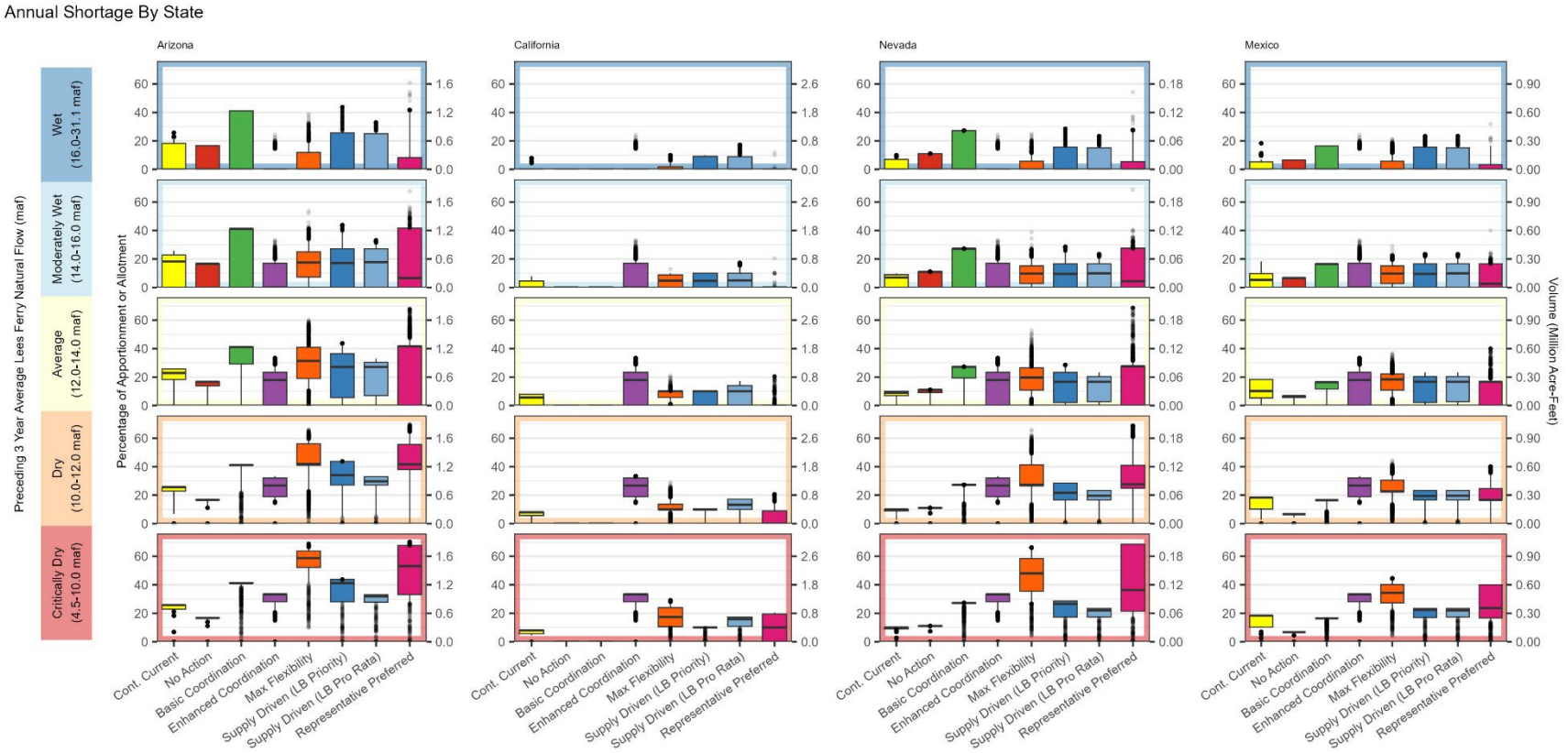
California

In California, the No Action and Basic Coordination Alternatives do not apply shortages to water users because they combine low maximum Lower Basin shortages with priority-based shortage distribution. However, low maximum Lower Basin shortages correspond to higher dead pool-related reductions. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives apply shortages to senior priority groups through pro rata-based distribution. The Maximum Operational Flexibility Alternative also affects Priorities 1 and 2 and PPRs in a small number of years in the Dry and Critically Dry Flow Categories. Priority 4 users are the most junior and experience the largest shortage volumes relative to their total rights. Under the Representative Preferred Alternative, Priority 4 median shortages are 0.0 kaf in the Dry Flow Category and 255.7 kaf in the Critically Dry Flow Category. Priorities 3a and 3b median shortages are 0.0 kaf and 100.4 kaf, respectively. The sum of the shortages across priority groups is shown in **Figure 3-16**. Shortage is also displayed by priority in **Figure TA 4-12** in **TA-4**, Water Deliveries.

Nevada

In Nevada, modeled shortages are primarily associated with Priority 8 users, who represent the vast majority of Nevada water rights. Other priority groups receive shortages only under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives because those alternatives use pro rata-based shortage distribution. Most action alternatives have higher median shortages as conditions become drier, while the Basic Coordination Alternative remains at 81.7 kaf because its maximum shortage is already applied in the Average Flow Category. Under the Representative Preferred Alternative, Priority 8 median shortages are 82.8 kaf in the Dry Flow Category and 108.9 kaf in the Critically Dry Flow Category. No other priority groups take shortage under this alternative. The sum of the shortages across priority groups is shown in **Figure 3-16**. Shortage is also displayed by priority in **Figure TA 4-13** in **TA-4**, Water Deliveries.

Figure 3-16
Calendar Year Shortage by State and Water Delivery Reductions to Mexico



Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Annual Depletions

Depletion, also referred to as total consumptive use or the net amount of water used, is defined as the amount of water diverted from the river minus return flow. Return flow is the portion of water diverted for use that is not consumed and returns to the river for subsequent downstream use. Across entities, alternatives, and the CCS Comparative Baseline, median depletions do not uniformly decrease as conditions become drier, but the percentage of years affected by dead pool-related reductions increases.

Arizona

In Arizona, modeled depletions are below 100 percent of apportionment in most years because shortages are applied frequently and conservation activity does not fully offset them. Depletions change little from the Average Flow Category to the Dry Flow Category, but years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and lower-percentile depletions decrease for most alternatives due to larger shortages and limited availability of, or access to, conserved water. Under the Representative Preferred Alternative, median Arizona depletions are 58.5 percent in the Dry Flow Category and 51.8 percent in the Critically Dry Flow Category, with dead pool-related effects in some outlier years and approximately 10 percent of years, respectively. The full range of annual depletions in Arizona across the different alternatives can be viewed in **Figure TA 4-14** in **TA-4**, Water Deliveries.

California

California's modeled depletions are below 100 percent of apportionment in most years under alternatives that apply shortages to the state. Under the No Action and Basic Coordination Alternatives, depletions below 100 percent are associated with dead pool-related reductions. Except under the Enhanced Coordination Alternative, median depletions change little from the Average Flow Category to the Critically Dry Flow Category, although years affected by dead pool-related reductions increase. Under the Representative Preferred Alternative, median California depletions are 95.8 percent in the Dry Flow Category and 86.0 percent in the Critically Dry Flow Category, with dead pool-related effects in some outlier years and fewer than 10 percent of years, respectively. The full range of annual depletions in California across the different alternatives can be viewed in **Figure TA 4-15** in **TA-4**, Water Deliveries.

Nevada

In Nevada, modeled depletions change little from the Average Flow Category to the Dry Flow Category, while years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and lower-percentile depletions decrease for most alternatives due to larger shortages and limited availability of, or access to, conserved water. Under the Representative Preferred Alternative, median Nevada depletions are 89.7 percent in the Dry Flow Category and 73.3 percent in the Critically Dry Flow Category. Dead pool-related effects occur in some outlier years in the Dry Flow Category and approximately 10 percent of years in the Critically Dry Flow Category. The full range of annual depletions in Nevada across the different alternatives can be viewed in F**igure TA 4-16** in **TA-4**, Water Deliveries.

Surplus

Surplus deliveries become more frequent as flow conditions become wetter. In the Average Flow Category, the Representative Preferred Alternative has the highest frequency of surplus deliveries at

18.0 percent of years, followed by the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at about 15 percent. All alternatives have surplus deliveries in fewer than 10 percent of years in the Dry Flow Category. In the Critically Dry Flow Category, only the CCS Comparative Baseline and the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives have any surplus deliveries, at fewer than 3 percent of years. The full range of frequency of surplus across the different alternatives can be viewed in **Figure TA 4-17** in **TA-4**, Water Deliveries.

Issue 4: Deliveries to Mexico

Issue 4 addresses how operational activities affect deliveries to Mexico. Refer to **TA-4**, Water Deliveries for greater details regarding the analysis of impacts as well as **Appendix N**, International Border Region of the Colorado River for additional information regarding water deliveries to the International Border Region.

Annual Reductions

For Mexico, modeled water delivery reductions generally increase as conditions become drier, with higher median reductions in the Dry and Critically Dry Flow Categories than in the Average Flow Category. In the Average Flow Category, the CCS Comparative Baseline and No Action Alternative have among the lowest median reductions, while the Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are around 20 percent. Under the Representative Preferred Alternative, Mexico's median water delivery reduction is 16.7 percent in the Dry Flow Category and 23.6 percent in the Critically Dry Flow Category. Refer to **Figure 3-16,** above, and the tables and figures in **TA-4,** Water Deliveries for further information.

Annual Depletions

Mexico's modeled depletions are below 100 percent of allotment in most years because delivery reductions are applied frequently and conservation activity does not fully offset them. Median depletions change little from the Average Flow Category to the Dry Flow Category, while years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and lower-percentile depletions decrease for most alternatives. Under the Representative Preferred Alternative, median Mexico depletions are 83.3 percent in the Dry Flow Category and 81.5 percent in the Critically Dry Flow Category, with dead pool-related effects in some outlier years and approximately 25 percent of years, respectively. Refer to **Figure TA 4-18** in **TA-4**, Water Deliveries for further information.

Issue 5: Lower Division States Combined Shortages

Issue 5 addresses how operational activities affect modeled distribution of combined shortages for the Lower Division States. As discussed in **Chapter 2**, the alternatives considered evaluate a distribution of shortages via priority and pro rata. Lower Division States' shortage distributions discussed under this issue were modeled with the SAM and ADM to estimate the volume of available water to entitlement holders or water users under Shortage Conditions over a specified range of shortage volumes. Refer to **TA-4**, Water Deliveries for greater details regarding the analysis of impacts as well as the **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation for additional information.

Tribal, Domestic, and Irrigation Shortage Impacts

For tribal users, priority-based alternatives result in greater shortage impacts than pro rata-based alternatives when comparing the same total shortage volume. Shortage impacts range from 209 to 582 kaf for priority-based alternatives and from 76 to 378 kaf for pro rata-based alternatives. Under the Representative Preferred Alternative, maximum 2027 and 2028 shortage impacts would be 346 kaf unless critical elevations at Lake Mead prompt consultation, while 2029-2060 modeling assumptions show a maximum potential impact of over 574 kaf.

For domestic users, priority-based alternatives result in greater shortage impacts than pro rata-based alternatives when comparing the same total shortage volume. Shortage impacts range from 277 to 1,501 kaf for priority-based alternatives and from 109 to 546 kaf for pro rata-based alternatives. Under the Representative Preferred Alternative, maximum 2027 and 2028 shortage impacts would be 858 kaf unless critical elevations at Lake Mead prompt consultation, while 2029-2060 modeling assumptions show a maximum potential impact of over 1,472 kaf.

For non-tribal irrigation users, pro rata-based alternatives result in greater shortage impacts than priority-based alternatives when comparing the same total shortage volume. Shortage impacts range from 2 to 1,211 kaf for priority-based alternatives and from 206 to 1,578 kaf for pro rata-based alternatives. Under the Representative Preferred Alternative, maximum 2027 and 2028 shortage impacts would be 70 kaf unless critical elevations at Lake Mead prompt consultation, while 2029-2060 modeling assumptions show a maximum potential impact of over 829 kaf.

Volumes of Shortage by State (Arizona, California, Nevada)

State specific distribution of shortages can be viewed in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

Issue 6: Upper Basin Conservation

This section describes how alternatives perform in terms of annual Upper Basin conservation activity. **Figure 3-17** shows three components of Upper Basin conservation activity.[9] The first column shows the annual total volume of conserved water accumulated by Upper Basin conservation. The second column reports the annual volume of conserved water that is created. The third column reports the annual volume that is converted to system water.

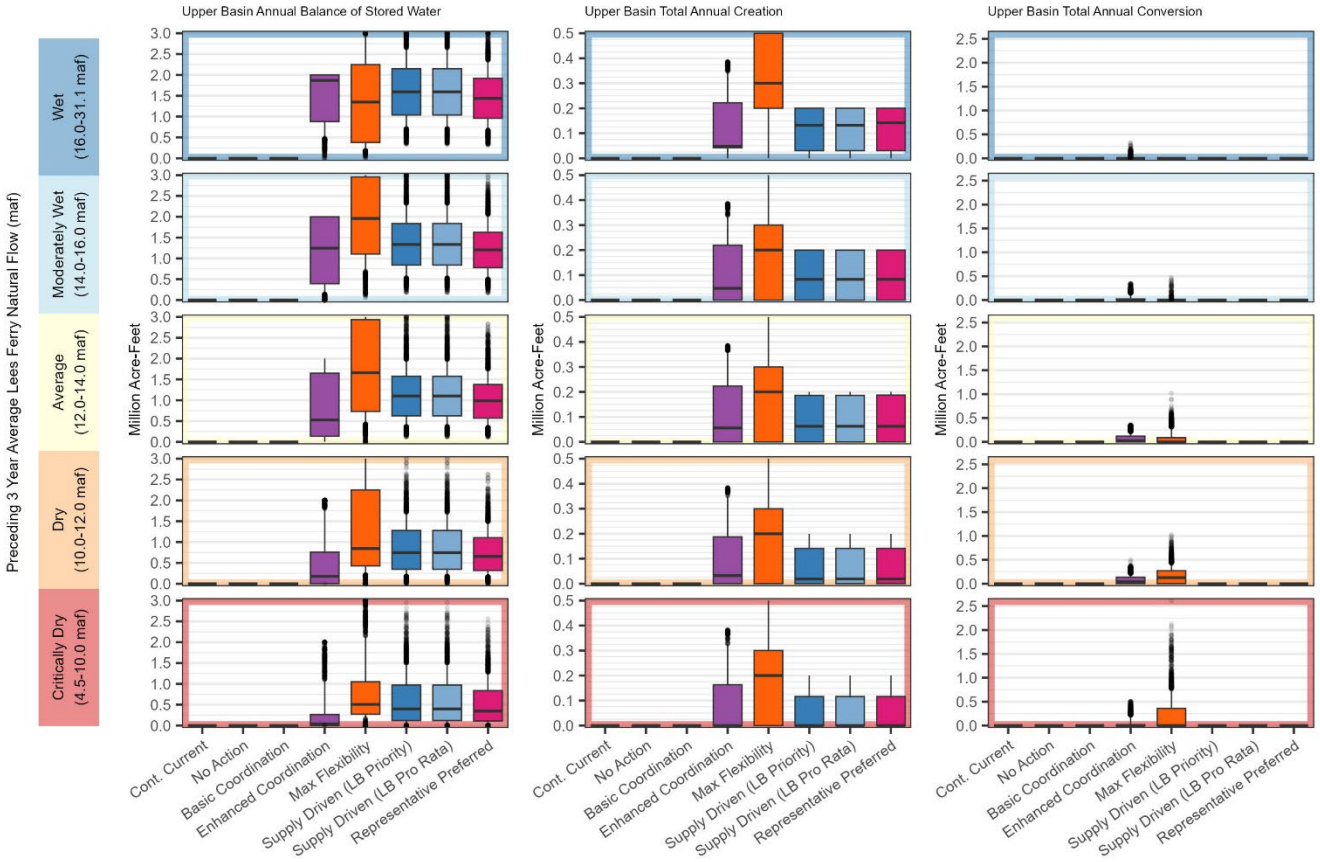
There is zero accumulation, creation, or conversion under the CCS Comparative Baseline or the No Action and Basic Coordination Alternatives, so the remainder of the discussion on **Figure 3-17** focuses on Enhanced Coordination, Maximum Operational Flexibility, Representative Preferred, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.[10]

Among alternatives with Upper Basin conservation, the Maximum Operational Flexibility Alternative has the highest median accumulation in the Average and Critically Dry Flow Categories and also has the highest median creation in those categories. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) does not convert conserved water because conservation is created as system

[9] For all alternatives except the Maximum Operational Flexibility Alternative, Lower Basin conserved water is stored in Lake Mead. For the Maximum Operational Flexibility Alternative, this water can be stored in Lake Mead, Lake Powell, or both.
[10] UB conservation activity is the same for both the LB Priority and LB Pro Rata approaches under the Supply Driven Alternative.

water. For the Representative Preferred Alternative, median accumulation is 1.0 maf in the Average Flow Category and 0.3 maf in the Critically Dry Flow Category. Median creation is about 0.1 maf in the Average Flow Category and 0.0 maf in the Critically Dry Flow Category.

Figure 3-17
Annual Upper Basin Conservation Activity



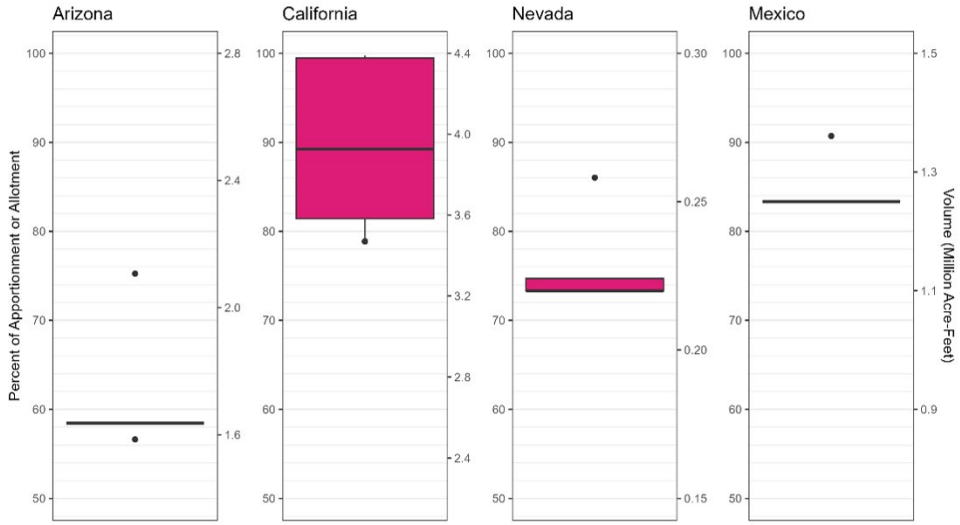
Note: In addition to the conservation volumes, the Supply Driven Alternative also includes "gap water" (see EIS **A**ppendix S, Additional Description of Alternatives, and **Appendix A,** CRSS Model Documentation). The modeled gap water volume increases with higher natural flow release percentages and drier hydrologic conditions. The median is 0.0 maf for the 60 and 65 percent natural flow release scenarios in the Average and Critically Dry flow categories, and increases to slightly over 0.1 maf and 0.8 maf, respectively, for the 70 percent scenario; the maximum gap water volume across all flow categories is approximately 1.1 maf. **Appendix D**, Sensitivity Analysis – Effects of Natural Flow Percentage Used for the Supply Driven Alternative, includes additional information on the modeled volumes of gap water.

Issue 7: Lower Division States' 2027-2028 Water Supply Determinations in the Representative Preferred Alternative

Under the Preferred Alternative decision framework, specific operating guidelines, including shortage volumes and distributions, will be developed and adopted periodically. It is anticipated that the first set of operating guidelines will cover 2027 and 2028. The Lower Division States' proposal for distributing shortages up to 1.5 maf on May 1, 2026, was incorporated in the Representative Preferred Alternative for 2027 and 2028, as described in **Chapter 2**.

In the Representative Preferred Alternative modeling, all 400 traces show a 1.5-maf Lower Basin shortage in 2027. In 2028, 148 traces remain at 1.5 maf, while 252 traces show larger shortages, with up to 3.0 maf in 3 traces. It is anticipated that volumes and distribution of shortages above 1.5 maf, should they be deemed necessary, would be developed based on consultation and are not analyzed in this Issue. **Figure 3-18**, below, shows the distribution of annual depletions for each state in 2027 and 2028 in the Representative Preferred Alternative. Median 2027-2028 depletions are approximately 1.6 maf for Arizona, 3.9 maf for California, 0.2 maf for Nevada, and 1.3 maf for Mexico. As a percent of apportionment or allotment, they are 58.5 percent for Arizona, 89.2 percent for California, 73.3 percent for Nevada, and 83.3 percent for Mexico.

Figure 3-18
Distribution of 2027-2028 Annual Depletions by State in the Representative Preferred Alternative



Summary Comparison of Alternatives

A summary of each issue is provided below, with additional information and details provided in **TA-4**, Water Deliveries**.**

Issue 1 considered whether the alternatives could affect apportionments to the Upper Division States. Because no changes to those apportionments are expected, no further impact analysis was needed.

Issue 2 assessed whether the alternatives could affect the Lower Division States' apportionments or water entitlements. The shortage distribution approaches were evaluated to explore potential concepts and impacts and not to change existing apportionments or entitlements. Related delivery effects are addressed under Issues 3, 5 and 7, and further summarized below.

Issue 3 evaluates effects on water supplies for the Lower Division States and Mexico, including shortages, Lake Mead dead pool-related reductions, conservation activity, depletions, delivery reductions, and surplus deliveries. Across alternatives, lower planned shortages tend to leave Lake Mead more vulnerable to dead pool-related reductions, while larger or more responsive shortages tend to provide stronger protection against those reductions. Differences among alternatives become more

pronounced under drier hydrology, and outcomes vary based on shortage volume, shortage distribution, conservation assumptions, and dead pool-related constraints. Under the Representative Preferred Alternative, modeled shortages are higher in the Critically Dry Flow Category than in the Dry Flow Category, which helps limit the frequency of Lake Mead dead pool-related reductions. Dead pool-related reductions remain limited in the Dry Flow Category and occur more often under Critically Dry conditions. The vulnerability analysis indicates that this alternative would likely become vulnerable to at least one dead pool-related reduction only under hydrologic conditions much drier than the observed record.

Issue 4 evaluates effects on Colorado River deliveries to Mexico, including annual delivery reductions and depletions. Across alternatives, Mexico generally receives its full allotment infrequently, and Lake Mead dead pool-related reductions occur more often under No Action and Basic Coordination than under several other alternatives. Under the Representative Preferred Alternative, Mexico's median depletions are similar in Dry and Critically Dry conditions, at 83.3 percent and 81.5 percent of allotment, respectively. Dead pool-related reductions affect about 25 percent of Critically Dry years, which is less frequent than under No Action but more common than under Maximum Operational Flexibility and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

Issue 5 considered how action alternatives would affect the distribution of combined shortages among Lower Division States water users. Modeled outcomes vary by distribution approach, with priority-based methods generally increasing shortages for tribal and domestic users, while pro rata methods tend to increase impacts to non-tribal irrigation users. Assuming a maximum shortage volume of 1.5 maf distributed based on the Lower Division States' May 1, 2026, proposal, the Representative Preferred Alternative, maximum modeled shortages in 2027 and 2028 would be 346 kaf for tribal users, 858 kaf for domestic users, and 70 kaf for non-tribal irrigation users[11]. For 2029 through 2060, the Representative Preferred Alternative assumes shortages up to 3.6 maf distributed by priority and potential for larger impacts, but actual shortage distributions would depend on the operating guidelines adopted under the Preferred Alternative framework.

Issue 6 examined how alternatives perform in terms of annual Upper Basin conservation activity. Upper Basin conservation activity occurs only under Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and the Representative Preferred Alternatives. No accumulation, creation, or conversion occurs under the CCS Comparative Baseline, and the No Action or Basic Coordination Alternatives. The Maximum Operational Flexibility Alternative generally has the highest annual accumulation and creation, while conversion is more limited overall. Under the Representative Preferred Alternative, accumulation and creation occur, but no conversion is modeled because no conversion mechanism is assumed.

Issue 7 evaluates the Lower Division States' 2027-2028 water supply determinations in the Representative Preferred Alternative, which assumes that up to 1.5 maf of shortage is distributed based on the Lower Division States' May 1, 2026, proposal (i.e., LB Priority). The Preferred Alternative establishes a decision framework, so actual shortage volumes and distributions may differ from those modeled. In 2027 all traces show a 1.5-maf Lower Basin shortage. While shortages greater

[11] While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative).

than 1.5 maf are modeled in 2028, they are not analyzed. The median 2027-2028 depletions are approximately 1.6 maf for Arizona, 3.9 maf for California, 0.2 maf for Nevada, and 1.3 maf for Mexico. As a percent of apportionment or allotment, they are 58.5 percent for Arizona, 89.2 percent for California, 73.3 percent for Nevada, and 83.3 percent for Mexico.

3.5 Geomorphology and Sediment

3.5.1 Affected Environment

This section describes how sediment and geomorphic processes shape the Colorado River below Glen Canyon Dam. Sandbars within the Grand Canyon provide key ecological, cultural, and recreational functions, supporting habitat, vegetation, archaeological resource protection, and camping areas along the river (Rubin et al. 2002; Mueller et al. 2018; Hazel et al. 2022; Reclamation 2024c). In addition, beaches provide camping areas for whitewater river trips, a significant driver of economic activity in the region.

Sandbars and channel-margin deposits depend on the river's sediment mass balance—the difference between the sediment entering and leaving the system. Before Glen Canyon Dam was built, the river carried large amounts of suspended sediment year-round. After the dam's completion, about 95 percent of the historical sediment supply from the Upper Basin was cut off, leaving the river with a long-term sediment deficit (Topping et al. 2000). As a result, the river now erodes sandbars and channel deposits faster than tributaries can replace them. Since the 1960s, most years have shown net erosion in Marble and Grand Canyons (Topping et al. 2021).

Dam operations also influence sediment behavior. Today's managed flows are much lower and more stable than historical floods, and minimum flows remain above levels that once allowed seasonal sand accumulation. Combined with the reduced sediment supply, these regulated discharges limit sand deposition, shorten the time available for sand storage, and increase erosion of beaches and sandbars (USGS 2011).

Downstream of Glen Canyon Dam, the Paria and Little Colorado Rivers are the dominant sediment sources. Upstream of the Paria, modern Glen Canyon receives little sediment input, making its sediment effectively nonrenewable (Grams et al. 2007). Sand delivered from tributaries tends to remain in the system only for a few months unless flows remain below roughly 9,000 cubic feet per second (cfs) (Topping et al. 2000; Rubin et al. 2002; USGS 2011). Most sediment ultimately continues downstream toward Lake Mead.

Fine sediment—sand, silt, and clay—is the primary material transported by the river and the main contributor to sandbar formation. Sand stored on the riverbed supplies the material that forms sandbars during high flows. Sediment transport increases with flow volume, turbulence, and changes in sediment size delivered by tributary floods. Deposition occurs in low-velocity environments such as recirculation zones of eddies and along channel margins, and storage varies with riverbed topography and tributary activity.

Geomorphically, the river consists of long pools separated by steep rapids formed at debris-fan deposits left by tributary debris flows. These fans constrict the channel, generate rapids, and create

recirculating eddies where sandbars form (**Figure TA 5-1** in **TA 5**, Geomorphology and Sediment). Most Grand Canyon sandbars are tied to these fan-eddy complexes and remain dynamic features that continually exchange sand with the river.

To counteract long-term sandbar erosion, Reclamation conducts HFEs that release large, short-duration floods from Glen Canyon Dam. HFEs are the only mechanism capable of producing water stages high enough to rebuild sandbars. Bar size generally increases during HFEs and then diminishes between them, with erosion highest immediately after floods. More frequent HFEs can increase sandbar size if sufficient sand is available (Grams et al. 2025).

3.5.2 Environmental Consequences

Methodology

All modeling used for this resource section was based on modeling performed by the USGS, GCMRC (Grams et al. 2025; Salter et al. 2025), and developed using the CRSS hydrological modeling results. Tributary sediment inputs from the Paria and Little Colorado Rivers were generated using the Wright et al. (2010) model. Outputs were fed to the Mueller and Grams (2021) sandbar model, recalibrated to the 2002–2024 period, based on the long-term monitoring program, and initialized using the January 1, 2025, volume. The model ran each alternative for all 400 traces and 3 initial conditions. Some modifications were made to the Mueller and Grams (2021) sandbar model to include additional sandbars in the calibration dataset, incorporate discharge-dependence into the erosion model, and assume a constant sandbar area (Salter et al. 2025). Two versions of the sandbar model were used to predict sandbar deposition: one for flow rates exceeding 8,000 cfs, the average daily discharge flow; and one for flow rates exceeding 25,000 cfs, the discharge at which sandbars will not be inundated during normal dam operations and will result in usable sandbars for recreational purposes (Salter et al. 2025). Except for modeled HFEs, the sandbar model did not include any sustained releases above 25,000 cfs over the calibration period. See **Section TA 5.2.1**, Methodology, in **TA-5**, Geomorphology and Sediment Resources, for additional information. The modeled sand transport, sandbar volumes, and reservoir operations data used in the impacts analysis is sourced from the USGS, GCMRC (Salter and Grams 2026).

Impact Analysis Area

The impact analysis area used for GCMRC sediment modeling data extends from the Colorado River at Glen Canyon Dam to Lake Mead, including sediment inputs from the Paria and Little Colorado River tributaries. The analysis area for the sandbar model (quantitative model) is from Lees Ferry (RM 0) through Diamond Creek (RM 225). The extent of this model is limited by the availability of study sites in the calibration dataset. However, it is expected that the findings for the reach between Lees Ferry and Diamond Creek are also representative for similar sandbars downstream to Separation Canyon (RM 240), the full-pool extent of Lake Mead. With low Lake Mead elevations, the Colorado River will cut new paths through the mouth of the reservoir, resulting in sediment redistribution that forms new bars and alters the reservoir's delta. Finer particles may remain in suspension and travel further downstream in the reservoir before settling, increasing sediment concentration near the upper reaches of Lake Mead. Impacts on water surface elevations and consequently erosion and deposition patterns in the delta region of Lake Powell may also result. Sediment redistribution within the reservoirs is not evaluated in this EIS due to the absence of an applicable model.

The proposed alternatives may modify the magnitude, timing, or variability of releases from Hoover Dam relative to existing operations. Any such changes would affect sediment resources downstream by altering sediment transport capacity and the degree to which available fine sediment is mobilized or retained. However, because the downstream reach is sediment-starved and the alternatives would not introduce new sources of sediment, significantly modify sediment supply, or change channel morphology, any effects on geomorphology and sedimentation downstream of Hoover Dam are expected to be negligible.

Assumptions

- Reclamation's future operations will remain responsive to hydrology, system conditions, and applicable legal and operational requirements. Reclamation will continue to follow 2016 LTEMP EIS and 2024 LTEMP SEIS guidelines, which include the planning and implementation team process that helps assess monthly release volumes and Secretarial decision-making.
- HFEs require sufficient sand in Marble Canyon (positive sand mass balance) and adequate Lake Powell water levels, both dependent on the chosen HFE duration.
- HFE releases can only be implemented above a 3,500-foot Lake Powell elevation, the elevation required for a release magnitude of 37,000 cfs (Reclamation 2024c; Salter et al. 2025).
- Non-HFE flows can deposit sand, but only sand deposited during flows above 25,000 cfs is considered usable for recreation.
- Sandbar building is fastest during the first 4 days; a 60-hour HFE produces strong deposition while allowing more frequent events and reducing interim erosion.
- Maximum ramp rates (4,000 cfs up / 2,500 cfs down per hour) are in accordance with 2016 and 2024 LTEMP guidelines.
- Sandbar volume modeling uses the assumption that HFEs are implemented as often as possible.
- Most of the sand input from the Paria and Little Colorado Rivers occurs during the summer-fall thunderstorm season between July 1 and November 1.
- If no HFE releases were implemented during the 1-year sediment accounting period, any positive sediment balance would be carried forward to the next accounting period.

Impact Indicators

Issues related to geomorphology and sedimentation that are evaluated in this section are listed below. Each of the five issues is associated with one or two "indicators," which serve as preferred minimum performance against which the issues are compared for the purpose of this analysis.

1. Water Availability in Lake Powell
2. Sand Mass
3. HFE Frequency and Duration
4. Sandbar Volume
5. Sand Transport

Issue 1: Water Availability

An HFE likely to enlarge sandbars requires enough water for a release rate of 37,000 cfs, generally considered the flow rate needed for significant deposition on certain sandbar types (Hazel et al. 2022). A 37,000 cfs release requires Lake Powell to be at or above 3,500 feet in April or November, when HFEs are typically scheduled. Alternatives that more frequently result in water levels greater than this threshold are therefore deemed preferable.

It should be noted that there are challenges to conducting HFEs at a Lake Powell elevation of 3,500 feet. Historically, the lowest elevation at which an HFE has been implemented was approximately 3,523 feet in April 2023. Since the models used an elevation of 3,500 feet as the lowest possible elevation at which HFEs could occur, it is likely that modeling overestimates the number or frequency of HFEs. **Table TA 5-1** in **TA 5**, Geomorphology and Sediment, shows the percentage of modeled HFEs by alternative that were above (or below) this lowest historical elevation.

Figure TA 5-2 in **TA 5**, Geomorphology and Sediment, depicts the ability of each alternative to maintain a Lake Powell pool elevation greater than 3,500 feet in November or April. The preferred minimum performance (the minimum result used as the comparison standard across alternatives) is shown in the highlighted row, which represents the percentage of futures that that an alternative exceeds 3,500 feet in November or April in 100 percent of years. The 3,500-foot threshold was selected because it is undesirable to ever miss the opportunity to take advantage of other favorable conditions such as large sediment loads from the Paria River. Over the 2027–2039 modeling period, the Maximum Operational Flexibility Alternative is the most robust meeting the preferred minimum performance in 97 percent of modeled futures (simulated hydrologic scenarios), followed by the Enhanced Coordination Alternative at 88 percent. The Representative Preferred Alternative meets the preferred minimum performance in 60 percent of futures.

The lowest Lake Powell elevation in the historical record (3,523 feet) is shown in **Figure TA 5-3** in **TA 5**, Geomorphology and Sediment, and displays the same information as **Figure TA 5-2**. With a 3,523-foot threshold, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 29 percent and 24 percent of modeled futures, which is lower than with the 3,500-foot threshold. **Figure TA 5-4** in **TA 5**, Geomorphology and Sediment, also demonstrates that these two alternatives would be the least vulnerable with respect to water availability. The Representative Preferred Alternative meets the preferred minimum performance in 14 percent of futures.

Issue 2: Sand Mass

The second condition required for an HFE release is the availability of sand. Sand that accumulates in Marble Canyon and is transported downstream outside HFE events does not result in sandbar formation. While management under the proposed alternatives would not attempt to control the sediment generation in the Paria River and Little Colorado River, the alternatives would affect how much of that sediment is available for HFEs by impacting the timing and magnitude of releases outside HFE releases.

Glen Canyon Dam releases for hydropower generation tend to be high in July and August (Reclamation 2016). This period also coincides with the summer-fall thunderstorm season in the Paria and Little Colorado watersheds that causes sand to be transported to Marble Canyon. Sand tends to

accumulate during September and October because the reduced releases are not enough to transport the sand downstream. Unless it is a particularly dry year, flows increase during the winter months, resulting in the transport of increasing quantities of sediment downstream.

While average flows must be lower than about 11,000 cfs to allow sediment accumulation under most initial conditions (bed conditions following a tributary sediment-supply event), flows greater than 15,000 cfs (900,000 af per month) are likely to be erosive regardless of those initial conditions (Salter et al. 2025). Therefore, futures with flows less than 900,000 af per month (i.e., non-erosive flows) for at least 90 percent of a simulation period are considered preferable. As detailed in **Figure TA 5-5** in **TA 5**, Geomorphology and Sediment, over the 2027–2039 modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meets this condition in 68 percent and 50 percent of simulated futures, respectively, while none of the other alternatives meet this condition in more than 41 percent of simulated futures (the Representative Preferred Alternative meets this conditions in 41 percent of simulated futures).

Historical data indicate that sandbar deposition typically occurs at HFE durations of 60 hours or greater (Grams et al. 2025). A 60-hour duration is required for successful beach building. **Figure TA 5-8** in **TA 5**, Geomorphology and Sediment, shows how often Marble Canyon sand mass exceeds 294,000 metric tons, the average transport capacity for a 60-hour HFE, in November or April. The highlighted row indicates the percentage of futures that meet this condition at least once every 4 years (the preferred minimum performance). Aside from the CCS Comparative Baseline, the percentage of futures in which November or April sand mass exceeds 294,000 metric tons at least every 4 years is comparable across the alternatives, ranging from 77 percent to 79 percent for the 2027–2039 modeling period. All alternatives perform better during each of the three subperiods than over the full modeling period, as the chance of at least one year with a sand mass below 294,000 metric tons increases over longer periods.

Issue 3: HFE Frequency and Duration

To allow for sandbar deposition that is sufficient to at least partially compensate for natural erosion in between HFEs, futures are considered preferable if they predict a spring or fall HFE of 60 hours or greater at least once every 4 years. A 60-hour duration is the minimum duration associated with significant sandbar deposition.

As shown in **Figure TA 5-9** in **TA 5**, Geomorphology and Sediment, for the 2027–2039 modeling period, aside from the CCS Comparative Baseline and No Action Alternative, the percent of futures in which annual HFE duration is greater than 60 hours at least once every four years, is comparable across the alternatives. The percentages range from 54 percent to 64 percent, but the Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best at 60 percent and 64 percent of simulated futures, respectively. This metric is limited by the availability of sand, given the high percentage with which Maximum Operational Flexibility and Enhanced Coordination Alternatives result in enough water for an HFE release (**Figure TA 5-2**). **Figure TA 5-10** in **TA 5**, Geomorphology and Sediment, also shows that Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives perform the best for HFE releases lasting 12 to 96 hours, with 46 percent, 43 percent, and 42 percent of years having HFE releases greater than or equal to 60 hours, respectively. This performance is notable because, excluding the HFE implemented on March 26, 1996, all HFEs implemented have been between 60 and 96 hours (Grams et al. 2025).

Figure TA 5-11 in **TA 5**, Geomorphology and Sediment, shows the distribution of HFE durations for the full sediment year (July 1 to July 1), fall, and spring. The distributions are further categorized into five hydrologic conditions based on the average natural flow rates at Lees Ferry over the preceding 3-year period. The figure illustrates a shift from fall HFE releases to spring HFE releases as the preceding 3-year average Lees Ferry natural flow decreases (i.e., conditions become drier). For the Critically Dry Flow Category (4.46–10.0 maf), only Maximum Operational Flexibility and Enhanced Coordination Alternatives result in HFE durations of any substantial duration, typically occurring in the spring, when snowpack is known and inflow volumes can be more easily predicted. It is important to note the modeling does not imply an expected outcome, just that HFEs remain possible. HFE triggers and final HFE implementation would be a result of the LTEMP process.

Issue 4: Sandbar Volume

The water level during a 25,000 cfs flow condition is the threshold above which camping and recreational activities are considered safe from flooding. The sandbar volume above this level represents the volume of "usable" sand in the canyon. As shown in **Figure TA 5-12** in **TA 5**, Geomorphology and Sediment, sandbar growth generally increases as hydrologic conditions become drier, and Enhanced Coordination and Maximum Operational Flexibility Alternatives perform the best in the Critically Dry Flow Category (4.46–10.0 maf).

Futures are considered preferable if *net* sandbar volumes exceed the sandbar volumes at the start of the simulation for 60 percent or more of the simulation period. As detailed in **Figure TA 5-13** in **TA 5**, Geomorphology and Sediment, the action alternatives perform well for this issue; at least 85 percent of futures have larger sandbar volumes than at the start of the 2027–2039 period for at least 60 percent of the simulation period. Even the CCS Comparative Baseline results in the preferred minimum performance for 68 percent of futures. For reference, the sandbar volume at the start of the simulation period is approximately 1,170 cubic meters (41,300 cubic feet). It is important to note that **Figure TA 5-13** in **TA 5**, does not show the percentage of years with year-over-year sandbar growth; if large increases in sandbar volume occur at the start of a period, it is very possible for sandbar volume to be lower than it was the year before and still be higher than it was at the start of the period. In addition, each future is based on a single simulation and consequently subdivided into the three modeling subperiods. The significant increase in sandbar volume during the 2027–2039 modeling period, when compared with the other subperiods, could be partially attributed to the modeling assumption that HFEs are implemented as often as possible.

Figure TA 5-14 in **TA 5**, Geomorphology and Sediment, shows this issue from a different perspective, providing the percentage of simulated years for which the maximum sandbar volume is less than or equal to a given value. Curves with lower placement in the plot imply better performance for that alternative. While the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results in the best performance, differences among the alternatives are minimal. The average sandbar volume for the 25 sandbar monitoring sites at the start of the full modeling period is 1,169.512 cubic meters (see **Section TA.5.2.1**, Methodology).

Issue 5: Sand Transport

While sand can be transported downstream with flows well below 37,000 cfs, lower flows are not conducive to sandbar formation and retention. The higher the fraction of sand transported above 37,000 cfs, the more sand will be available for sandbar formation (Hazel et al. 2022; Salter et al. 2025).

Figure TA 5-15 in **TA 5**, Geomorphology and Sediment, shows the percentage of futures for which the total sand mass transported by flow rates above 37,000 cfs (sandbar-forming flow rates) exceeds a given fraction over the 34-year simulation period. Futures are considered preferable if the fraction of sand mass transported by sandbar-forming flow rates is at least 0.4 (40 percent of the sand transport). The highlighted row provides the percentage of futures that meet this criterion. Under the Maximum Operational Flexibility Alternative, 85 percent of simulated futures are considered preferable—that is, at least 40 percent of sand mass is transported by sandbar-forming flow rates in 85 percent of simulated futures. The Enhanced Coordination Alternative is similarly robust, at 83 percent of simulated futures. Performance for the Supply Driven (both LB Priority and LB Pro Rata approaches), Representative Preferred, and Basic Coordination Alternatives are similar, with 78 percent, 76 percent, and 75 percent of futures considered preferable, respectively.

Summary Comparison of Alternatives

Taken as a whole, the results of the analysis suggest that the Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with respect to geomorphology and sediment. This appears to be largely due to their superior ability to preserve Lake Powell water levels above 3,500 feet in November and April, one of two conditions required for an HFE release (**Figure TA 5-2** in **TA 5**, Geomorphology and Sediment). In contrast, the Representative Preferred Alternative performs noticeably weaker in this category, though slightly better than the other alternatives. Impacts to sand mass in Marble Canyon, the other condition required for an HFE release, are comparable across alternatives, including the CCS Comparative Baseline (**Figure TA 5-7** in **TA 5**, Geomorphology and Sediment). During the driest climatic conditions (for which the preceding 3-year average Lees Ferry natural flow is less than 10.0 maf), Maximum Operational Flexibility and Enhanced Coordination Alternatives are the only two alternatives that would result in HFEs of any substantial duration, typically occurring in the spring.

3.6 Water Quality

3.6.1 Affected Environment

Salinity

The Colorado River Basin Salinity Control Forum reviews and makes salinity criteria recommendations for the Colorado River every 3 years. Flow-weighted average annual salinity criteria for the Colorado River are currently 723 milligrams per liter (mg/L) below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam (Colorado River Basin Salinity Control Forum 2023). The water quality standards for salinity in the Colorado River were approved by the Environmental Protection Agency (EPA) and are reviewed every three years pursuant to Section 303(c)(1) of the Clean Water Act (Colorado River Basin Salinity Control Forum 2023).

Salinity control is accomplished through multiple programs. Federal agencies, including Reclamation, the BLM, and the U.S. Department of Agriculture, pursue improvements on federal lands to reduce salinity loading to the Colorado River (Reclamation 2022). Since the construction of Glen Canyon Dam, annual salinity concentrations downstream of Glen Canyon Dam have varied between 400 and 600 mg/L (Richards 2025). In a review of sampling efforts from 2007–2023, Reclamation has not exceeded the salinity criteria for the Colorado River. See **Section TA 6.1.1**, Salinity, in **TA 6**, Water Quality, for more information on salinity in the planning area and historical salinity concentrations in the Lower Basin.

Temperature

Lake Powell is a monomictic[12] reservoir with strong thermal stratification through much of the spring, summer, and early fall; this means the water is layered, with distinct temperatures and chemical characteristics. Generally, Lake Powell's epilimnion, or uppermost layer, ranges from 25 to 30 degrees Celsius (°C; 77 to 86 degrees Fahrenheit [°F]) in the summer, dropping to 6 to 10 °C (42.8 to 50 °F) in the winter (Deemer et al. 2023). Lake Powell's hypolimnion, or deeper layer, ranges from 6 to 9 °C (42.8 to 48.2 °F) year-round. Since the early 2000s, lower water levels in Lake Powell have led to warmer summer water temperatures in the Colorado River below Glen Canyon Dam (Reclamation and NPS 2016). Temperatures in the Colorado River in the Grand Canyon vary widely over space and time and are primarily controlled by the discharge and temperature released from Glen Canyon Dam and solar radiation dynamics along the river corridor (Mihalevich et al. 2020).

Lake Mead is also monomictic. Lake Mead inflow temperatures are a function of Glen Canyon Dam discharges and downstream weather conditions (Reclamation 2016). Lake Mead's hypolimnion is around 12 °C (53.6 °F) year-round. Its epilimnion ranges from about 14 to 29 °C (57.2 to 84.2 °F) in the spring, summer, and early fall, and drops to about 13 to 15 °C (55.4 to 59 °F) in the winter (SNWA 2023). Further declines in reservoir elevation, coupled with rising air temperatures, may continue to lead to warmer releases from Lake Mead, though this depends on whether the lower Hoover Dam outlet is used (Hannoun et al. 2022).

Harmful Algal Blooms and Nutrients

Nutrients, such as nitrogen and phosphorus, are essential for life, but excess nutrients in water can harm human health and ecosystems and impact recreational opportunities (USGS 2019a; NPS 2025a). In the project area, the most severe algal blooms are caused by cyanobacteria, which can produce toxins that can threaten drinking water quality and harm human health (USGS 2019a). In Lake Mead, water within Las Vegas Bay has the highest concentration of nutrients due to discharges of highly treated wastewater from the Las Vegas metropolitan area. Wastewater is a persistent contributor of phosphorus, whereas stormwater with higher phosphorus contributions is an acute contributor but a minor source overall. This is because storm events are infrequent. Since phosphorus is a limiting nutrient in the Colorado River system, these contributions support algal growth (USGS 2012). Lowering reservoir levels could increase the concentration of nutrients and temperatures, especially in shallow areas, which could be more favorable for algal growth (Hannoun et al. 2022).

[12] Monomictic waterbodies are those that mix completely during one mixing period each year.

Dissolved Oxygen

Dissolved oxygen is a critical factor for fish health. Research on dissolved oxygen thresholds for both warmwater and cold-water fish species shows that salmonids are particularly vulnerable to low dissolved oxygen concentrations compared with warmwater species (Saari 2018). Sustained dissolved oxygen levels below 3 mg/L can significantly reduce survival rates and feeding efficiency, whereas concentrations in the range of 6 to 9 mg/L are considered optimal for growth and survival across all life stages (EPA 1986).

Generally, Lake Powell's dissolved oxygen concentrations are at their highest in the spring to early summer, when inflows are well oxygenated and wind-induced mixing is high. Low dissolved oxygen concentrations move through the reservoir and closer to the dam during the summer into the fall because of organic matter decomposition and chemical reactions that consume oxygen. Dissolved oxygen gradually increases in the winter as a result of the higher oxygen-carrying capacity of cold water and the natural mixing during turnover. When water is discharged through the river outlet works, it becomes well aerated and increases the dissolved oxygen levels in the tailwaters, but only while the river outlet works are open.

Recently, dissolved oxygen levels in Lake Powell and the Glen Canyon Dam tailwaters[13] have been low compared with historical dissolved oxygen levels. This is due to low reservoir elevations and the increasing reservoir age (Deemer et al. 2025). Dissolved oxygen levels below Glen Canyon Dam vary throughout the year, falling as low as 2.2 mg/L in the summer and rising as high as 9 to 10 mg/L in the spring (GCMRC 2025). Dissolved oxygen increases approximately 1 mg/L between Glen Canyon Dam and Lees Ferry. Low dissolved oxygen conditions improve downstream of the Paria Riffle and Badger Rapids as the water is reaerated through whitewater action.

In Lake Mead, dissolved oxygen levels decrease in the bottom of Las Vegas Bay as a result of high decomposition of organic matter from the Las Vegas Wash. When there are greater nutrients in surface water, generally more decomposition and low oxygen occur in bottom waters. Monitoring is ongoing to determine the cause of decreased dissolved oxygen concentrations in isolated areas, but the driver is likely higher temperatures from inflows (Reclamation and NPS 2016).

Metals, Perchlorate, and Per- and Polyfluoroalkyl Substances

The planning area contains sources of metals and regulated chemicals, including perchlorate and per- and polyfluoroalkyl substances (PFAS), although metals are not a typical concern in the planning area and mitigation programs have successfully reduced perchlorate concentrations below applicable regulatory limits throughout the lower basin (Hannoun and Tiejen 2022). Generally, as reservoir elevations decrease, the dilution capacity of reservoirs like Lake Powell and Lake Mead would also decrease. Decreased dilution capacity from lower reservoir elevations could result in greater concentrations of pollutants of concern. For more information, see **Sections TA 6.1.5**, Metals; **TA 6.1.6**, Perchlorate; and **TA 6.1.7**, PFAS, in **TA 6**, Water Quality.

[13] Tailwater refers to waters located immediately below the dam. It is the reach of river immediately downstream of a reservoir that is heavily influenced by reservoir characteristics. Tailwaters are generally expected to have water quality that is more similar to the water quality in reservoirs compared with reaches farther downstream.

3.6.2 Environmental Consequences

Methodology

The analysis methodology for water quality is based on a combination of DMDU; CRSS; GCMRC Dissolved Oxygen and Temperature Models for Glen Canyon, Lees Ferry, and Grand Canyon; and qualitative analysis. For detailed information on the dissolved oxygen and water temperature models, see **Section TA 6.2.1**, Methodology, in **TA 6**, Water Quality, for more information.

CRSS simulates Colorado River Basin conditions decades into the future and can account for hydrologic uncertainty. CRSS is a monthly time-step model that produces reservoir elevations, dam releases, and salinity concentrations. Refer to **Appendix A**, CRSS Model Documentation for more details on model documentation.

In this section, salinity is analyzed as it relates to the salinity criteria set by the Colorado River Salinity Control Forum. For information on salinity concentration and salinity related to the potential effects on resources in the International Border Region, see **Appendix N**, International Border Region of the Colorado River.

Conditional box plots and robustness heat maps that describe impacts on water quality can be found in **TA 6**. Refer to **Section 3.2**, Analysis Methods, for additional information on interpreting the DMDU conditional box plots, robustness heat maps and vulnerability bar plots.

While reduced water deliveries could have impacts to downstream municipal users, the analysis does not include an analysis of these impacts since the operations of municipal water providers fall outside of Reclamation's regulatory authority and are carried out independently by these third parties.

Impact Analysis Area

The analysis area for water quality is the geographic and temporal scope introduced in **Section 3.2**, Analysis Methods. Due to the data available, the analysis was limited to surface water quality.

Assumptions

- There will be modifications in quantity, timing, temperature, and quality of water released from Glen Canyon Dam and Hoover Dam.

Impact Indicators

- Salinity
- Temperature
- Dissolved oxygen
- Reservoir elevation
- Dilution capacity

Issue 1: How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect salinity?

Increased salinity concentrations from human activities pose a threat to drinking water, irrigation, agricultural production, municipal water supplies, and infrastructure. Reservoirs like Lake Powell and

Lake Mead influence salinity by reducing the effect of salinity transport downstream and possibly acting as a source or a sink (Deemer 2020). Dam releases are typically from deeper in the water column and generally have elevated salinity concentrations relative to surface waters. As reservoir water levels drop, reservoir salinity can often increase (Zohary and Ostrovsky 2011).

Using CRSS outputs, annual flow-weighted average salinity concentrations below Hoover Dam, below Parker Dam, and at Imperial Dam were simulated under various hydrologic conditions. Under all alternatives, a majority (90 percent or greater) of simulated futures did not exceed the salinity criteria in even the most challenging hydrologic conditions. For the Average Flow Category, maximum simulated annual flow-weighted salinity concentrations exceeded the salinity threshold below Hoover Dam under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives. See **Figure TA 6-4** in **TA 6**, Water Quality, for box plots depicting these annual flow-weighted average salinity concentrations.

Under the Dry Flow Category, all alternatives exceeded the threshold, with an increasing number in the Critically Dry Flow Category due to the low reservoir elevations associated with these hydrologic conditions. The highest median salinity concentrations occur in the Enhanced Coordination Alternative, with the difference between the alternatives largest in the Critically Dry Flow Category. Simulated flow-weighted average salinity concentration median values did not exceed salinity thresholds at all sites under all alternatives, even under the driest flow scenarios. Therefore, no significant negative impacts on salinity were associated with any of the alternatives.

All alternatives are truly robust, meeting the preferred level of performance in 90 percent of futures or greater in the first decadal period (that is, 2027 to 2039) below Hoover Dam, below Parker Dam, and at Imperial Dam. See **Figures TA 6-5**, **TA 6-6**, and **TA 6-7** in **TA 6**, Water Quality, for robustness plots of the percentage of futures in which the salinity concentration is less than salinity criteria below Hoover Dam, below Parker Dam, and at Imperial Dam in 100 percent of years.

In a vulnerability analysis of conditions that could cause salinity concentrations below Hoover Dam to exceed 723 mg/L in one or more years, if the future includes a 10-year average flow of 11.8 maf or lower, modeling results do not indicate undesirable performance for all alternatives; over 75 percent of the reference hydrology include averages this low or lower. Further, the hydrologic conditions associated with undesirable performance for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) (6.8 maf) are less than that of any previously observed conditions in the reference hydrology (7.8 maf). See **Figure TA 6-8** in **TA 6**, Water Quality, for additional information on the vulnerability plot displaying conditions that could cause salinity below Hoover Dam to exceed 723 mg/L in one or more years under each alternative.

Issue 2: How would reservoir storage, reservoir releases, and the corresponding changes in river flows downstream of the reservoirs affect water temperature?

Water temperature strongly influences biological and chemical processes. For example, the temperature of dam releases affects fish population dynamics in downstream river segments, and elevated reservoir temperatures can lead to harmful algal blooms. **Sections TA 8.2.3**, Issue 2 and **TA 8.2.5**, Issue 4 in **TA 8**, Biological Resources – Fish and Other Aquatic Species, describe the impacts of temperature on fish and other aquatic species at temperature thresholds of 12 °C, 16 °C, and 20 °C (53.6 °F, 60.8 °F, and 68 °F).

Using outputs from GCMRC Dissolved Oxygen and Temperature Models for Glen Canyon, Lees Ferry, and Grand Canyon, the annual average of daily temperatures and annual maximum Colorado River temperatures at Lees Ferry were simulated under various hydrologic conditions. As shown in **Figure TA 6-9** in **TA 6**, Water Quality, at Lees Ferry under the Average Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives had lower median simulated annual average and maximum daily temperatures, with a narrower interquartile range, compared with the other alternatives at both Lees Ferry and Pearce Ferry.

Under the Dry and Critically Dry Flow Categories, simulated median values for temperatures increased across alternatives, compared with the Wet and Moderately Wet Flow Categories, and the Enhanced Coordination Alternative had the lowest median values for simulated average and maximum temperatures. Additionally, the interquartile ranges increased across all alternatives, indicating more variability in the annual average of daily temperatures and maximum temperatures as flow conditions become drier. For additional information on the simulated average and maximum Colorado River temperatures at Lees Ferry under various hydrologic conditions, see **TA 6**, Water Quality.

Considering the impacts on fish and other aquatic species, the Enhanced Coordination Alternative had the greatest number of simulated futures that maintained cooler water temperatures at Lees Ferry. These cooler temperatures are beneficial for rainbow trout, and they limit smallmouth bass reproduction, but these temperatures also inhibit native fish growth and reproduction. See **TA 8**, Biological Resources – Fish and Other Aquatic Species, for additional information on changes in water temperature from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry and impacts to sportfish, native Grand Canyon fish, and nonnative predatory fish. See **TA 14**, Recreation, for more detailed information on temperature impacts associated with sportfish populations.

Issue 3: How would reservoir storage, reservoir releases, and the corresponding changes in river flows downstream of the reservoirs affect dissolved oxygen?

Dissolved oxygen dynamics can be affected by reservoir drawdowns through several pathways, including remobilization of deposited sediment as water levels change. As older reservoirs like Lake Powell experience lower elevations, there is greater metalimnion dissolved oxygen consumption, with larger spring snowmelt inflows furthering dissolved oxygen declines (Deemer et al. 2025). Dissolved oxygen is also affected by certain operations. For example, as reservoir levels decrease below 3,490 feet at Lake Powell, use of the river outlet works is triggered; this leads to high dissolved oxygen concentrations downstream of Glen Canyon Dam due to aeration as water passes through the river outlet works (Vernieu 2010).

Using outputs from GCMRC Dissolved Oxygen and Temperature Models for Glen Canyon, Lees Ferry, and Grand Canyon, minimum annual dissolved oxygen concentrations released from Glen Canyon Dam under each alternative were simulated under various hydrologic conditions. Under dry conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives generally had higher simulated minimum annual dissolved oxygen concentrations than the other alternatives, but generally lower simulated minimum annual dissolved oxygen concentrations under critically dry conditions. See **Figure TA 6-11** in **TA 6**, Water Quality, for additional information on minimum annual dissolved oxygen concentration released from Glen Canyon Dam under various hydrologic conditions.

Below 3,490 feet at Lake Powell, releases from the river outlet works would effectively aerate the water, but its use would be limited over the long term to protect Glen Canyon Dam infrastructure. Therefore, elevation at Lake Powell below 3,490 feet and minimum annual dissolved oxygen concentration greater than 2 mg/L were considered. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred level of performance in a majority of futures for the first decadal period (that is, 2027-2039). The simulated minimum dissolved oxygen concentrations are greater than 2 mg/L in the fewest number of futures under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives in the first decadal period (that is, 2027-2039). See **Figure TA 6-12** in **TA 6**, Water Quality, for additional information on the robustness of minimum annual dissolved oxygen concentration where the Lake Powell elevation stays above 3,490 feet.

Due to the limitation of long-term use of the river outlet works, vulnerability was only analyzed for conditions that could cause dissolved oxygen concentration less than 2 mg/L or Lake Powell elevation below 3,490 feet in more than 10 percent of years. Only the Enhanced Coordination and Maximum Operational Flexibility Alternatives resulted in undesirable performance (dissolved oxygen concentrations from Glen Canyon Dam releases falling below 2 mg/L or Lake Powell elevations below 3,490 feet) below the lowest 25 percent of previously observed hydrologic conditions. The hydrologic conditions associated with undesirable performance for the CCS Comparative Baseline and the No Action, Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives fall within a majority of hydrologic conditions that have already been observed. See **Figure TA 6-14** in **TA 6**, Water Quality, for additional information on the vulnerability analysis of conditions that could cause a dissolved oxygen concentration less than 2 mg/L or Lake Powell elevation below 3,490 feet in more than 10 percent of years.

Dissolved oxygen impacts on fish were also analyzed by considering dissolved oxygen concentrations less than 3 mg/L, which is a concentration that leads to reduced survival and feeding efficiencies. Under the Critically Dry Flow Category (4.46–10.0 maf), Lake Powell elevations stay above 3,490 feet, and the simulated minimum annual dissolved oxygen concentration is greater than 3 mg/L, which is critical for fish survival and feeding efficiencies, in at least 90 percent of the years in the greatest percent of futures under the Enhanced Coordination Alternative. See **TA 8**, Biological Resources – Fish and Other Aquatic Species, for more information on the impact of dissolved oxygen on fish.

Issue 4: How would reservoir storage, reservoir releases, and the corresponding changes in river flows downstream of the reservoirs affect harmful algal blooms and nutrients?

Cyanobacteria blooms can alter physical and chemical water quality properties, threaten aquatic species, and release toxins into waterbodies, leading to health effects on recreationists and affecting water supplies. In a mixed-methods literature review assessing risk for cyanobacteria and phytoplankton in response to water level changes, with potential application to Lake Powell and Lake Mead, cyanobacteria were substantially more likely to increase in response to decreases in water levels. The review also suggested that the prevalence of cyanobacteria increases when reservoir water levels decline, subsequently increasing the risk of cyanobacterial blooms in reservoirs with more severe fluctuations in water levels (Hoffman 2025). However, examples also exist of no marked water quality response to long-term water level drawdown, including at Lake Mead. For example, Lake Mead

experienced dramatic multiyear reductions in the water level with no apparent effects on nutrient or chlorophyll concentrations (Hannoun and Tietjen 2022).

In a qualitative analysis of simulated reservoir elevations at Lake Powell, the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would pose an increased risk of cyanobacterial blooms due to the lower simulated Lake Powell elevations. These increased risks would be greatest under the Critically Dry Flow Category (4.46–10.0 maf) associated with lower reservoir elevations. The Enhanced Coordination and Maximum Flexibility Alternatives had the greatest number of simulated futures in which the maximum annual change in water surface elevation was less than 30.71 feet in 5 years or more out of 10 years during the first decadal period (that is, 2027-2039). This could decrease the risk of cyanobacterial blooms associated with severe fluctuations in water levels under the Enhanced Coordination and Maximum Flexibility Alternatives, compared with the other alternatives. For additional information about water quality impacts related to cyanobacteria, see **Section TA 6.2.5**, Issue 4, in **TA 6**, Water Quality. For additional information on how operational activities for the various alternatives would affect reservoir elevations, see **Section TA 3.2.1**, Issue 1: Reservoir Elevations, in **TA 3**, Hydrologic Resources.

Issue 5: How would reservoir storage and reservoir releases affect reservoir dilution capacity?

Generally, as reservoir elevations decrease, the dilution capacity of reservoirs like Lake Powell and Lake Mead also decreases. Decreased dilution capacity from lower reservoir elevations could result in greater concentrations of pollutants of concern, such as PFAS and perchlorate.

Given the current data and modeling capabilities, the impacts of the alternatives on pollutants of concern could not be quantitatively assessed. A qualitative review of reservoir elevations under **Section TA 3.2.1**, Issue 1: Reservoir Elevations, indicates that the impact of decreased dilution capacity associated with lower reservoir elevations on pollutants of concern, such as PFAS and perchlorate, would be greatest under the alternatives with the lowest median WY minimum reservoir elevations, including the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. However, this impact would likely be negligible since it is unlikely that any of the reservoir elevations under the alternatives would significantly reduce dilution capacity or increase the concentration of pollutants of concern.

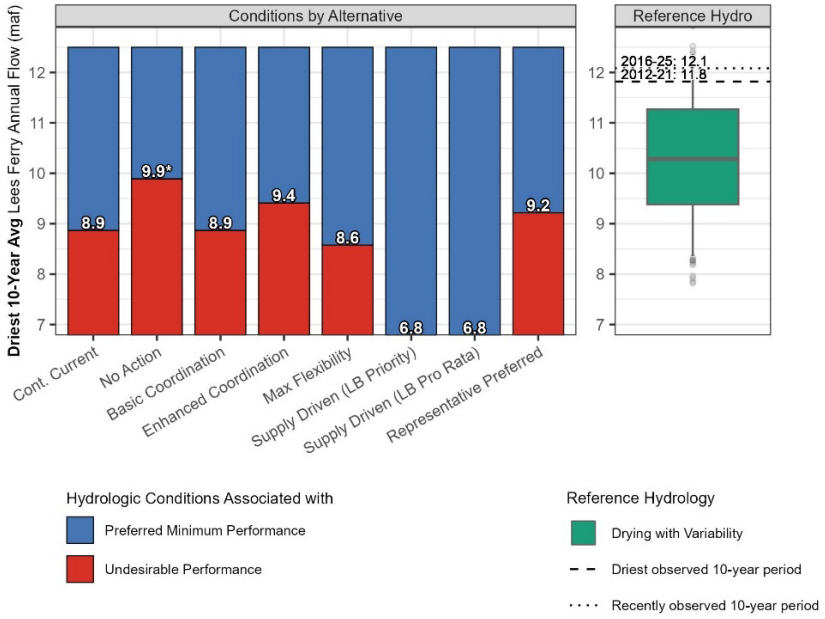
Summary Comparison of Alternatives

In a comparison of the vulnerability analyses for conditions that could cause undesirable performance for simulated salinity and dissolved oxygen, **Figure 3-19** shows that, generally, the CCS Comparative Baseline, and the No Action, Basic Coordination, and Representative Preferred Alternatives are vulnerable to undesirable performance under a relatively wide range of conditions for both simulated salinity and dissolved oxygen compared to the least vulnerable alternatives. **Figure 3-19** also shows that there are vulnerability trade-offs between the two indicators associated with the other alternatives.

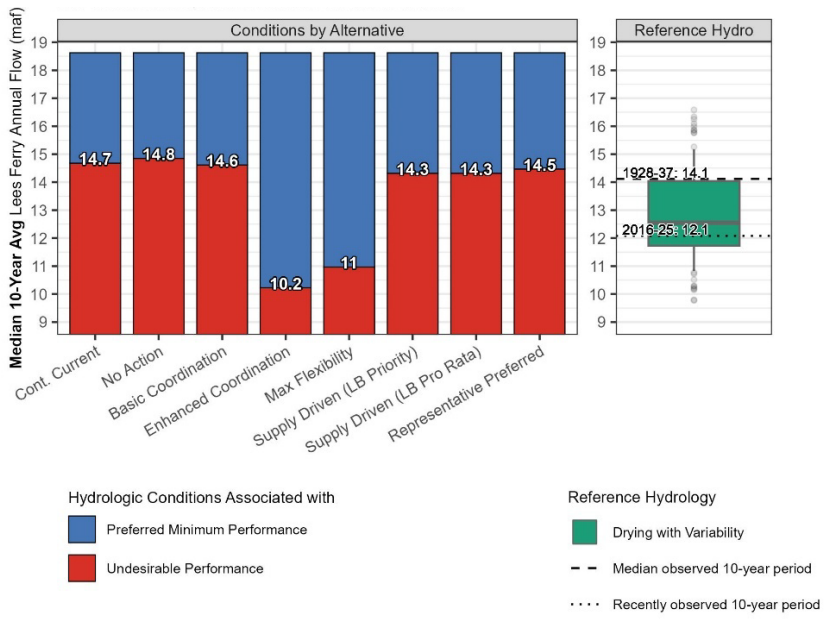
Considering simulated salinity, under the Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches), the hydrologic conditions associated with undesirable performance (a 10-year drought averaging 6.8 maf or lower) are drier than any conditions in the observed record or the reference hydrology ensemble, in which the lowest 10-year drought averaged 7.8 maf, so they have

Figure 3-19
Conditions that Could Cause Undesirable Performance for Salinity and Dissolved Oxygen

Salinity*



Dissolved Oxygen**



*Undesirable performance for salinity means conditions that could cause salinity below Hoover Dam above 723 mg/L in one or more years.
**Undesirable performance for dissolved oxygen means conditions that could cause dissolved oxygen concentration less than 2 mg/L or Lake Powell elevation below 3,490 feet in more than 10 percent of years.

low vulnerability. However, vulnerability with respect to dissolved oxygen is high: the median 10-year-average flows associated with undesirable performance under the Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches) was 14.3 maf; this is wetter than the median observed 10-year period flow from 1928 to 1937 (14.1 maf). Additionally, almost 75 percent of the traces in the reference hydrology ensemble have median 10-year average flows drier than this.

Similarly, there are vulnerability trade-offs associated with the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Considering simulated dissolved oxygen, the Enhanced Coordination Alternative would be vulnerable if the median 10-year-average flow was 10.2 maf or drier, and the Maximum Operational Flexibility Alternative would be vulnerable in the median 10-year-average flow was 11 maf or drier; these conditions are drier than 90 to 100 percent of the traces in the refence hydrology ensemble and far below any observed 10-year-average flow. However, considering simulated salinity, the Enhanced Coordination and Maximum Operational Flexibility Alternatives result in undesirable performance under hydrologic conditions that are greater than the Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches). Still, more than 75 percent of the traces in the reference hydrology ensemble are wetter than these values, so the vulnerability is not high.

In comparison of relative values for Lake Powell's reservoir elevation and the Colorado River temperature at Lees Ferry, the alternatives that had higher reservoir elevations would decrease the risk for cyanobacterial blooms and increase the dilution capacity for pollutants. These alternatives also had lower temperatures. This is because the Colorado River temperature at Lees Ferry is influenced in part by Lake Powell's reservoir elevation. The Enhanced Coordination Alternative had the highest median values for WY minimum Lake Powell elevations and the lowest average and maximum temperatures, compared with the other alternatives. The Maximum Operational Flexibility Alternative also had some of the highest median values for WY minimum Lake Powell elevations and some of the lowest average and maximum temperatures, compared with the other alternatives. The Representative Preferred Alternative had the third highest median WY minimum.

Lake Powell elevation so this alternative poses a decreased risk for cyanobacterial blooms and decreased risk of greater concentration of pollutants of concern but it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.

Overall, the Enhanced Coordination and Maximum Operational Flexibility Alternatives had the lowest vulnerability for dissolved oxygen and relatively lower maximum and average Colorado River temperatures at Lees Ferry, compared with the other alternatives. These two alternatives were slightly more vulnerable with respect to simulated salinity compared with the Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches); however, the hydrologic condition associated with undesirable salinity performance for the Enhanced Coordination and Maximum Operational Flexibility Alternatives were still drier than more than 75 percent of the traces in the reference hydrology ensemble.

3.7 Air Quality

3.7.1 Affected Environment

This section presents the existing conditions, regulatory framework, applicable laws, and available studies and resources related to air quality. Congress enacted the Clean Air Act (CAA) to ensure acceptable and nonhazardous air quality for the people of the U.S. The EPA subsequently established the National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment, referred to as criteria pollutants (EPA 2025a). **Table TA 7-1**, in **TA 7**, shows the current NAAQS for each pollutant, which have been fully adopted by Utah, Arizona, and Nevada. The air pollutant sources in Arizona, Nevada, and Utah fall under different jurisdictions and each state implements regulations that further govern fugitive dust, which are discussed in more detail in **Section TA 7.1.4.**

For each criteria pollutant, the EPA classifies areas as in "attainment" if the area complies with the NAAQS or as "nonattainment" if one or more of the NAAQS are exceeded. Areas for which available data are not sufficient to make an attainment status designation are listed as unclassifiable. Air quality is considered in "attainment" or "unclassifiable" for all criteria pollutants within the Arizona counties of La Paz, Mohave, Coconino, Yavapai, and Navajo and the Utah counties of Washington, Kane, and San Juan. Clark County, Nevada, has been designated as serious nonattainment for the 2015 8-hour ozone (O_3) standard and a maintenance area for carbon monoxide (CO) and particulate matter less than 10 microns in diameter (PM_{10}); the county is considered in "attainment" or "unclassifiable" for all other pollutants (EPA 2025b). Air quality within Yuma County, Arizona, has been designated as marginal nonattainment for the 2015 8-hour O_3 standard and moderate nonattainment for PM_{10}; it is considered in "attainment" or "unclassifiable" for all other pollutants. Therefore, the General Conformity Rule would apply for O_3, CO, and PM_{10}. The general conformity de minimis thresholds for all pollutants are presented in **Table TA 7-2**.

CAA regulations also control the release of hazardous air pollutants (HAPs), which are chemicals that are known or suspected to cause cancer or other serious health effects. The NAAQS have not been set for HAPs; rather, HAP emissions are controlled by source type– or industrial sector–specific regulations using maximum achievable control technology standards. There are no project-specific applicable maximum achievable control technology requirements regarding HAPs, as these standards only apply to stationary sources within specific industrial groups.

Several tables present the existing conditions for the analysis area. Criteria pollutants are monitored throughout various parts of the country. The EPA uses the criteria pollutant monitoring data to determine a "design value" for each pollutant and averaging time, which can be compared with the NAAQS. The most recent available 2024 design values for the analysis area counties are provided in **Table TA 7-3**, **Table TA 7-4,** and **Table TA 7-5**. The design value for O_3 for Clark County exceeds the NAAQS for O_3 (0.70 parts per million), and the number of exceedances of the PM_{10} NAAQS exceeds the standard for Clark County. No other design value listed in **Table TA 7-3**, **Table TA 7-4,** and **Table TA 7-5** exceed or approach proximity to the NAAQS (EPA 2025c). In addition, triennially, the EPA publishes a comprehensive summary of air emissions data, known as the National Emissions Inventory (NEI). **Table TA 7-7** through **Table TA 7-10** present the most recent 2020 emissions for the six criteria air pollutants and HAPs for the U.S.; the states of Arizona, Nevada, and Utah; and all

counties in the analysis area. The EPA uses the NEI to develop and review regulations, conduct air quality modeling, and conduct risk assessments to understand how air pollution may affect the health in communities across the country.

As set forth in the CAA, the EPA developed and implemented the Prevention of Significant Deterioration (PSD) regulations to protect public health and welfare and to preserve, protect, and enhance the air quality in areas of special value. As part of the PSD, the EPA classifies airsheds as Class I, which are areas for which the PSD regulations provide special protection, or Class II, which allows for moderate pollution increases and reasonable growth, while still applying stringent air quality constraints (NPS 2023a). **Table TA 7-11** presents the Class I areas located within the analysis area and those located in counties adjacent to the analysis area. For those Class I areas that are national parks, the table also provides visibility data. **Table TA 7-11** shows that the visibility ranges from fair to good. In addition, the NPS monitors and evaluates deposition to identify parks that are most at risk and where conditions are declining or improving (NPS 2024a). **Table TA 7-12** shows that nitrogen deposition conditions are fair to poor and sulfur deposition conditions are good, with trend data unavailable for most locations.

Regional modeling, studies, and data discussed that pertain to the analysis area are as follows:

- Historical to present Lake Powell and Lake Mead pool elevations: Figures showing the Lake Powell pool elevations for 1963 through 2025 and the Lake Mead pool elevations for 1935 through 2025.
- Lake Powell and Lake Mead Modeling: This is a 2024 study to model the exposed shoreline area and potential dust emissions at the two reservoirs (Sankey et al. 2024).
- Lake Mead Annual High and Low Elevations: Annual high and low elevations of Lake Mead for years 1935–2024 are available from Reclamation.
- Lake Powell Annual High and Low Elevations: Annual high and low elevations of Lake Powell for years 1964–2024 are available from Reclamation.
- Lake Mead Mapping: The USGS completed a detailed geophysical mapping of the floor of Lake Mead during 1999, 2000, and 2001. These data indicate that a large volume of sediment carried by the Colorado River has accumulated in Lake Mead.
- Lake Powell Mapping: This is a survey of Lake Powell for the purpose of calculating the elevation-area-capacity relationships in Lake Powell.
- Impact of Lost Generation at the Glen Canyon Powerplant: This report presents data showing the changes in generation sources for each of the years 2024–2027.
- Owens Lake California Environmental Quality Act (CEQA) Initial Study: Discussed the Owens Lake Dust Mitigation Program and the objective to implement dust control measures on Owens Lake to reduce emissions. The potential future change for Lake Powell and Lake Mead may also highlight the need for a similar dust mitigation program, should water levels decrease below 500 km^2, for each lake.

Past and present climate trends and impacts are provided for Nevada, Arizona, and Utah. An analysis of regional climate impacts concluded that the rate of average annual temperature increases in the southwest U.S. was among the most rapid nationally (IPCC 2021). Analysis of past records indicates an overall increase in regional temperatures, including in the analysis area. The National Oceanic and

Atmospheric Administration's National Centers for Environmental Information released its climate summaries by state in 2022. The climate summaries for the analysis area states are summarized. More detailed climate discussions for each state can be found through the State Climate Summaries web page (NOAA 2022).

3.7.2 Environmental Consequences

Methodology

This section examines potential effects on air quality resources under the action alternatives and the No Action Alternative, compared with the CCS Comparative Baseline. Potential impacts are considered for the following air quality resources: shoreline exposure area, fugitive dust emissions, and how changes in hydropower impact CO_2e.

CRSS is used in the hydrologic analysis, and the output is organized into five flow condition categories. The five flow condition categories are framed as the Wet Flow Category (16.0–31.11 maf), Moderately Wet Flow Category (14.0–16.0 maf), Average Flow Category (12.0–14.0 maf), Dry Flow Category (10.0–12.0 maf), and Critically Dry Flow Category (4.46–10.0 maf). There are 400 different hydrologic traces for each year over a 34-year period, as shown in **Figure TA 7-2** in **TA 7**, Air Quality.

To support evaluating how potential changes in reservoir water storage might affect potential dust emissions from subaerially exposed reservoir sediment, the subaerial shoreline area and potential dust emissions within Lake Powell and Lake Mead were modeled for this analysis. The shoreline exposure analysis used previously published topographic and bathymetric surveys and geologic mapping (Hirschberg and Pitts 2000; Jones and Root 2021, 2022; Ferrari 2001; Root et al. 2019; Root and Jones 2022; Twichell et al. 2003; Twichell and Cross 2009; Wilson et al. 1969) with new predictions of potential dust emissions using the FENGSHA model (Mallia et al. 2017). The results are presented as Glen Canyon and Lake Mead exposed shoreline area and associated emission rates (Fischella et al. 2026). Resource modeling predicts: 1) the area of subaerial shoreline exposed as a function of monthly water surface elevations at Lake Powell and Lake Mead (respectively); 2) potential dust emissions ($kg/m^2/hr$) as a function of monthly water surface elevations at Lake Powell and Lake Mead modeled using FENGSHA with sustained winds for 15 m/s (approximately 35 miles per hour) for 6 hours. The results are presented as Glen Canyon and Lake Mead exposed shoreline area and associated emission rates (Fischella et al. 2026). Impacts on shoreline exposure and fugitive dust emissions are then described using conditional box plots, as well as DMDU robustness heat maps and vulnerability bar plots. In a conditional box plot, the bold center line of each box represents the median value, the top and bottom of each box capture the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines. Refer to **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU robustness heat maps and vulnerability bar plots.

Subaerially exposed shoreline area and potential dust emissions increase as water storage decreases. However, the relationships differ at the two reservoirs due to surficial geology, deposition of reservoir sediment, and topographic and bathymetric terrain; Glen Canyon Dam impounded a deep canyon-bound segment of the Colorado River at Lake Powell, whereas Hoover Dam impounded a comparably broader valley of the river at Lake Mead. When Lake Powell and Lake Mead are filled to minimum power pool, approximately 500 km^2 (123,552 acres) of shoreline is exposed at each

reservoir, although this estimate is highly approximate. The minimum power pool, or the lowest reservoir water level at which turbines can continue generating electricity efficiently, is 3,450 feet for Lake Powell and 950 feet for Lake Mead.

Lake Mead $PM_{2.5}$ emissions below 500 million kg (1,102 million pounds) ensures that fugitive dust would be minimized protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power. Lake Powell $PM_{2.5}$ emissions below 450 million kg (992 million pounds) ensures that fugitive dust would be minimized protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power.

The increase or decrease in metric tons of CO_2e emissions due to changes in hydropower generation at Glen Canyon Dam, Hoover Dam, Parker Dam, and Davis Dam are presented in conditional box plots. The conditional box plot for each dam compares the median CCS Comparative Baseline generation to the median generation for each alternative and multiple natural flow groups. In each year of every modeled future, the difference in annual hydropower generation between the CCS Comparative Baseline and each alternative was computed to determine the change in generation, whether that be an increase or a decrease. The annual change in generation was multiplied by the 2025 and 2050 Emissions and Generation Resource Integrated Database/National Laboratory of the Rockies emission factor. **Table TA 7-19** and **Table TA 7-20** in **TA 7**, Air Quality, show how the 2025 and 2050 weighted average emission factors were calculated. These emission factors represent the potential CO_2e from each resource type per megawatt-hour (MWh) and the current and future resource mix percentages for the Western Regional Climate Center energy production. The weighted emission factors are multiplied by the changes in MWh for each alternative and flow category.

Impact Analysis Area

The geographic scope of the air quality resources analysis includes Lake Powell to the SIB, which includes Mohave, Coconino, Yavapai, and Navajo Counties in Arizona; Washington, San Juan, and Kane Counties in Utah; and Clark County, Nevada. Specifically, the shoreline exposure analysis area includes Lake Powell and Lake Powell. The analysis areas for changes in CO_2e due to hydropower generation include Glen Canyon Dam, Hoover Dam, Parker Dam, and Davis Dam. The climate trends analysis area is discussed for the western U.S.

Assumptions

- The hydrologic resources results are direct results from CRSS. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation.
- The National Laboratory of the Rockies publishes life cycle assessments and which CO_2e emission factors are associated with each type of electricity generation (NLR 2021).
- The EPA 2023 Emissions and Generation Resource Integrated Database was used to determine the North American Electric Reliability Corporation resource mix (coal, natural gas, oil, nuclear, hydropower, biomass, wind, solar, and geothermal sources) for the Western Electricity Coordinating Council region (EPA 2025d).
- The U.S. Energy Information Administration's Annual Energy Outlook 2023 (EIA 2023) provides the potential generation mix for 2050.

The equivalency calculator is used to convert emissions into concrete, understandable terms, such as the annual CO_2 emissions of cars, households, and powerplants (EPA 2025e).

Impact Indicators

Specific impact indicators were selected to help frame the air quality resources analysis for each alternative. The following indicators were used to assess impacts:

- Shoreline Exposure: These are effects on the shoreline exposure area due to operational activities.
- Shoreline Dust Emissions: These are effects on shoreline dust emissions due to operational activities.
- Potential Change of CO_2e Emissions due to a Fluctuation of Hydropower Generation: These are effects on CO_2e emissions due to operational activities.

Issue 1: How would changing flow characteristics affect the potential exposed shoreline, fallowed agricultural lands, and fugitive dust?

Changes in water storage in lakes can affect the area of shoreline sediment exposed subaerially and potentially available for aeolian transport. This resource modeling evaluates how potential changes in reservoir water storage might affect potential dust emissions from subaerially exposed reservoir sediment. Relationships between potential dust emissions and water storage could be useful for evaluating air quality and related resource impacts associated with Colorado River water management decisions.

Figure TA 7-4 in **TA 7**, Air Quality, shows the WY maximum exposed shoreline area for Lake Powell and Lake Mead. In the Average Flow Category (12.0–14.0 maf), Lake Powell alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from 225 to 500 km^2 (55,598 to 123,552 acres) of maximum exposed shoreline. The CCS Comparative Baseline, as well as the No Action, Basic Coordination, Representative Preferred and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, all show similar medians of roughly 400 km^2 (98,842 acres) of maximum exposed shoreline. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have lower and comparable medians of about 300 km^2 (74,132 acres) of maximum exposed shoreline.

The Lake Mead alternatives have varying Average Flow Category distributions, with the 25th to 75th percentiles across all alternatives spanning from 125 to 500 km^2 (30,888 to 123,552 acres) of maximum exposed shoreline. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative has the lowest median maximum exposed shoreline, at about 230 km^2 (56,834 acres). The No Action Alternative has the highest median value at roughly 470 km^2 (66,718 acres). The Representative Preferred Alternative has a median maximum exposed shoreline of about 300 km^2 (74,132 acres), with the 25th to 75th percentiles across all alternatives spanning from 220 to 390 km^2 (54,393 to 96,371 acres) of maximum exposed shoreline.

In the Dry Flow Category (10.0–12.0 maf), the 25th to 75th percentiles across all Lake Powell alternatives span from approximately 300 to 545 km^2 (74,132 to 134,672 acres) of maximum exposed shoreline. The Enhanced Coordination and No Action Alternatives have the lowest and highest median maximum exposed shoreline at about 365 and 520 km^2 (90,194 and 128,495 acres),

respectively. For Lake Mead, the 25th to 75th percentiles across all alternatives span from approximately 200 to 530 km^2 (49,421 to 130,966 acres) of maximum exposed shoreline. The Supply Driven (both LB Priority and LB Pro Rata approaches) and No Action Alternatives have the lowest and highest median maximum exposed shoreline at about 360 and 490 km^2 (88,598 and 121,082 acres), respectively.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Lake Powell maximum exposed shoreline, the median maximum exposed shoreline is about 450 km^2 (111,197 acres), with the 25th to 75th percentiles across all alternatives spanning from 415 to 475 km^2 (102,549 to 117,375 acres) of maximum exposed shoreline. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Powell maximum exposed shoreline, the median maximum exposed shoreline is about 495 km^2 (122,317 acres), with the 25th to 75th percentiles across all alternatives spanning from 484 to 520 km^2 (119,599 to 128,495 acres) of maximum exposed shoreline. For the Lake Mead maximum exposed shoreline, the median maximum exposed shoreline is about 400 km^2 (98,842 acres), with the 25th to 75th percentiles across all alternatives spanning from 280 to 445 km^2 (69,190 to 109,962 acres) of maximum exposed shoreline. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Mead maximum exposed shoreline, the median maximum exposed shoreline is about 450 km^2 (111,197 acres), with the 25th to 75th percentiles across all alternatives spanning from 395 to 489 km^2 (97,606 to 120,835 acres) of maximum exposed shoreline.

Lake Mead Robustness

Figure TA 7-5 in **TA 7**, Air Quality, depicts the ability of each alternative to maintain Lake Mead shoreline exposure below the specified area in every month. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures in which the exposed shoreline area for each alternative remains below 500 km^2 (123,552 acres) in every month. For Lake Mead, 500 km^2 (123,552 acres) is a very rough approximation of the area of shoreline exposed when the reservoir is filled to minimum power pool (950 feet). Keeping the Lake Mead shoreline exposure below 500 km^2 (123,552 acres) ensures that fugitive dust will be minimized. Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The color of a heat map square corresponds with the percent of futures that meet the specified level of performance, which increases from less than 10 percent of futures keeping the Lake Mead shoreline exposure area below the specified value in every month (least robust), to greater than 91 percent of futures keeping the Lake Mead shoreline exposure area below the specified value in every month (most robust). The higher the percentage, the more probable Lake Mead shoreline exposure will remain below the specified km^2 under most future hydrologic scenarios.

Figure TA 7-5 in **TA 7**, Air Quality, shows that the Enhanced Coordination, Representative Preferred, and Maximum Operational Flexibility Alternatives are the most robust at staying below 500 km^2 (123,552 acres) of shoreline exposure over the full modeling period (shown in the top row), doing so in 80 percent, 82 percent, and 88 percent of modeled futures, respectively. The No Action Alternative has the worst performance at a 35 percent success rate over the full analysis period.

In the first decadal breakout (2027–2039), the Representative Preferred, Maximum Operational Flexibility, and Enhanced Coordination Alternatives meet the preferred minimum performance in 92

percent, 93 percent and 88 percent of modeled futures, respectively, which is more robust than the other alternatives. The No Action Alternative has the worst performance at a 54 percent success rate over the full analysis period.

For the full modeling period, 2027–2039 modeling period, 2040–2049 modeling period, and 2050–2060 modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently achieve 71–100 percent robustness, while the No Action Alternative only reaches a maximum of 51 percent robustness at even the lowest levels of performance for the 500 km^2 (123,552 acres) of shoreline exposure category.

Figure TA 7-6 in **TA 7**, Air Quality, shows flow conditions that could cause the Lake Mead shoreline exposure area to be above 500 km^2 (123,552 acres) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-5**, which defined a future as successful when exposed shoreline area for an alternative remains below 500 km^2 (123,552 acres) in every month. For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The Basic Coordination Alternative would likely be vulnerable to a Lake Mead exposed shoreline area greater than 500 km^2 (123,552 acres) under a 10-year average Lees Ferry natural flow of 10.2 maf or drier, which is slightly less vulnerable than the CCS Comparative Baseline, which is likely to be vulnerable if the 10-year average is 10.5 maf or drier. The No Action Alternative is vulnerable to a 10-year average of 11.4 maf, which is similar to the driest observed 10-year average of 11.8 maf. The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 8.7 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, 100 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Lake Powell Robustness

Figure TA 7-7 in **TA 7**, Air Quality, depicts the performance of each alternative with regard to keeping the Lake Powell shoreline exposure area below 500 km^2 (123,552 acres) in every month. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at staying below 500 km^2 (123,552 acres) of shoreline exposure over the full modeling period (shown in the bottom row), doing so in 81 percent and 95 percent of the futures, respectively. The No Action Alternative has the worst performance at a 16 percent success rate over the full analysis period.

In the first decadal breakout (2027–2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 87 percent and 98 percent of modeled futures, respectively. The No Action Alternative meets the preferred minimum performance in 25 percent of modeled futures. The CCS Comparative Baseline, as well as the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives meet the preferred minimum performance in 54 percent, 45 percent, and 46 percent of futures, respectively. Based on the

planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 66 percent of futures in the 2027-2039 modeling period.

For the full modeling period, 2027–2039 modeling period, 2040–2049 modeling period, and 2050–2060 modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently achieve 81–100 percent robustness, while the No Action Alternative only reaches a maximum of 48 percent robustness at even the lowest levels of performance for the 500 km^2 (123,552 acres) of shoreline exposure category.

Figure TA 7-8 in **TA 7**, Air Quality, looks at flow conditions that could cause the Lake Powell shoreline exposure area to be above 500 km^2 (123,552 acres) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-7**, Air Quality, which defined a future as successful when exposed shoreline area for an alternative remains below 500 km^2 (123,552 acres) in every month. For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The Enhanced Coordination Alternative modeling results indicate undesirable performance at a 10-year average flow of 9 maf or drier, which occurs in less than 25 percent of the Drying with Variability traces. The Maximum Operational Flexibility Alternative is least vulnerable, with no Drying with Variability traces occurring below the undesirable performance level of 6.8 maf.

The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 10.9 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, 30 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Shoreline Exposure

Figure TA 7-9 in **TA 7**, Air Quality, shows the WY maximum shoreline dust emissions for Lake Powell and Lake Mead. In the Average Flow Category (12.0–14.0 maf), Lake Powell alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from approximately 105 to 460 million kg (231 to 1,014 million pounds) of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) as a result of shoreline exposure. The CCS Comparative Baseline and the Supply Driven (both LB Priority and LB Pro Rata approaches), Basic Coordination, and No Action Alternatives all have similar median maximum monthly emission rates of around 300 million kg of $PM_{2.5}$ as a result of shoreline exposure. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have lower medians. Therefore, these two alternatives would result in less $PM_{2.5}$ than the other alternatives.

The Lake Mead alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from 80 to 540 million kg (176 to 1,190 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure. with the No Action and Supply Driven (both LB Priority and LB Pro

Rata approaches) Alternatives displaying the highest and lowest values at about 500 and 160 million kg (1,102 and 353 million pounds) of $PM_{2.5}$, respectively. As flow categories get drier for WY minimums, the medians for all Lake Powell and Lake Mead alternatives increase the millions of kg of $PM_{2.5}$. As flow categories get wetter for WY minimums, the potential $PM_{2.5}$ decreases.

Lake Mead Robustness

Figure TA 7-10 in **TA 7**, Air Quality, depicts the performance of each alternative with regard to keeping Lake Mead $PM_{2.5}$ below 500 million kg from a shoreline exposure area. The color of a heat map's square corresponds with the percentage of futures that meet this level of performance; the percentage increases from less than 10 percent of futures keeping the Lake Mead emissions below 100 million kg (220 million pounds) (least robust) to greater than 91 percent of futures keeping the Lake Mead emissions above 500 million kg (1,102 million pounds) (most robust). The higher the percentage, the more likely Lake Mead will remain above the minimum power pool (950 feet) under most future hydrologic scenarios. Keeping the Lake Mead emissions below 500 million kg (1,102 million pounds) ensures that fugitive dust would be minimized, which would protect air quality in the area.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at staying below 500 million kg (1,102 million pounds) over the full modeling period, doing so in 69 percent and 76 percent of the futures, respectively. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can meet the preferred minimum performance in 64 percent of modeled futures. The No Action Alternative has the worst performance at a 22 percent success rate over the full analysis period. The Representative Preferred Alternative meets staying below 500 million kg (1,102 million pounds) of shoreline dust emissions robustness criteria in 58 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 74 percent of futures in the first modeling period.

In the first decadal breakout (2027–2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum performance in 79 percent and 84 percent of modeled futures, respectively, which is more robust than the other alternatives. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 74 percent of futures in the 2027-2039 modeling period.

For the full modeling period, 2027–2039 modeling period, 2040–2049 modeling period, and 2050–2060 modeling period, the Maximum Operational Flexibility Alternative consistently achieves 71–100 percent robustness.

Figure TA 7-11 in **TA 7**, Air Quality, looks at flow conditions that could cause Lake Mead emissions above 500 million kg (1,102 million pounds) during at least one or more months. The Enhanced Coordination, Maximum Flexibility, Representative Preferred, and Supply Driven (both LB Priority and LB Pro Rata) Alternatives are vulnerable to similar conditions: 10-year droughts of 9.9 maf, 9.6 maf, 10.2 and 10.2 maf, respectively. The CCS Continued Baseline is more vulnerable, with a 10-year drought of 11.0 maf likely to cause undesirable performance. The No Action Alternative is the most vulnerable; Lake Mead would likely go below 1,000 feet elevation in a 10-year drought averaging 12.1

maf. From 2012 to 2021, the 10-year average was 11.8 maf; therefore, the No Action Alternative is just below the vulnerability of conditions that have already occurred.

Lake Powell Robustness

Figure TA 7-12 in **TA 7**, Air Quality, depicts the performance of each alternative with regard to keeping Lake Powell $PM_{2.5}$ from a shoreline exposure area below 450 million kg (992 million pounds). The color of a heat map's square corresponds with the percentage of futures that meet this level of performance; the percentage increases from a less than 10 percent of futures keeping the Lake Powell emissions below 150 million kg (331 million pounds) (least robust), to a greater than 91 percent of futures keeping the Lake Powell emissions above 450 million kg (992 million pounds) (most robust). Keeping the Lake Powell emissions below 450 million kg (992 million pounds) ensures that fugitive dust would be minimized, which would protect air quality in the area.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at staying below 450 million kg, doing so in 78 percent and 91 percent of the futures, respectively. The Basic Coordination, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives perform similarly to the CCS Comparative Baseline, if not slightly worse, succeeding in 21 percent, 22 percent, and 22 percent of futures, respectively, over the full analysis period. The No Action Alternative has the worst performance at a 10 percent success rate over the full analysis period. The Representative Preferred Alternative meets staying below 450 million kg (992 million pounds) of shoreline dust emissions robustness criteria in 38 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 59 percent of futures in the first modeling period.

In the first decadal breakout (2027–2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 84 percent and 96 percent of modeled futures, respectively, which is considerably more robust than the other alternatives. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 59 percent of futures in the 2027-2039 modeling period.

For the full modeling period, 2027–2039 modeling period, 2040–2049 modeling period, and 2050–2060 modeling period, the Maximum Operational Flexibility Alternatives consistently achieves 91–100 percent robustness (dark blue in color).

Figure TA 7-13 in **TA 7**, Air Quality, looks at flow conditions that could cause Lake Powell emissions above 450 million kg during at least one or more months. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to similar conditions: 10-year droughts of 9.2 and 6.8 maf, respectively. The No Action Alternative has a 10-year drought of 12.2, which is above the reference hydrology box plot averages for 2012–2021 (11.8 maf) and 2015–2024 (12.6 maf). Therefore, the No Action Alternative is more vulnerable and likely to cause undesirable performance.

Other effects are the potential dust-on-snow effects, which may occur when reservoir elevations are low, and there are more dust mobilization and potential acceleration of runoff. Also, changing flow characteristics can affect the fallowing of agricultural lands, especially in regions that rely on consistent irrigation from reservoirs.

Changes in flow characteristics may affect agricultural operations in regions dependent on reservoir-based irrigation, particularly if reduced dam releases decrease water availability for downstream users. In such cases, farmers may be forced to fallow some or all of their fields to conserve limited water supplies for higher-value crops and avoid unsupported planting and irrigation costs. As discussed in **TA 16.2.2** of **TA 16**, Socioeconomics, including **Figure TA 16-1**, estimates of potential fallowed acreage are based on simplifying assumptions regarding water availability, crop profitability, and agricultural decision-making and are intended for regional-scale economic analysis rather than site-specific predictions. Fallowed agricultural lands can be a source of fugitive dust emissions, especially under dry, unvegetated conditions. Screening-level estimates of windblown dust emissions can be developed using generalized U.S. EPA AP-42 emission factors, with PM_{10} emissions typically ranging from approximately 0.1 to 0.5 tons per acre per year depending on soil stability, vegetation cover, and wind exposure; $PM_{2.5}$ emissions are generally a smaller fraction of PM_{10} emissions. Because emissions depend on site-specific conditions such as soil characteristics, vegetation, wind, dust control measures, and the extent and timing of fallowing, these estimates are intended only to indicate the potential magnitude of fugitive dust emissions and are not site-specific predictions.

Clark County, Nevada, is the only county in the analysis area that has been designated as serious nonattainment for the 2015 8-hour O_3 standard and a maintenance area for CO and PM_{10} (EPA 2025b). The potential shoreline exposure discussed above has the potential to increase particulate matter that could further exacerbate the current PM_{10} issue in Clark County.

Issue 2: How would lake reservoir elevations and releases impact power generation and CO_2e emissions?

Issue 2 addresses how operational activities for the various alternatives affect reservoir elevations and, therefore, impact hydropower generation. When there is a change of hydropower, there would be a potential change in CO_2e emissions because emissive alternative energy generation with varying emissions would compensate for this reduction. The box plots compare present-day and potential future electricity mixes, reporting metric tons of CO_2e based on the 2025 resource mix emission factor on the left axis and the 2050 resource mix emission factor on the right axis, using the MWh increase or decrease for each alternative and flow category. Only the 2025 resource mix is discussed in detail. This is because the 2050 resource mix results would have lower metric tons of CO_2e because the emission factor includes more alternative energy resources.

Figure TA 7-14 in **TA 7**, Air Quality, shows the changes in CO_2e emissions due to a fluctuations in hydropower at Glen Canyon Dam for each flow category and the alternatives. In the Average Flow Category (12.0–14.0 maf), the Glen Canyon Dam alternatives have varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 288-metric-ton decrease to a 115-metric-ton increase of CO_2e emissions. The No Action Alternative has a median close to zero, representing the smallest decrease relative to the CCS Comparative Baseline. The Enhanced Coordination (134 metric tons decrease of CO_2e) and Maximum Operational Flexibility (143 metric tons decrease of CO_2e) Alternatives have similar medians, resulting in the largest decrease in CO_2e emissions relative to the CCS Comparative Baseline.

In the Critically Dry Flow Category (less than 10.0 maf), all the alternatives, except the Enhanced Coordination and Maximum Operational Flexibility Alternatives, are projected to result in similar behavior, in terms of medians and variability, since they all show a potential increase of CO_2e

compared with the CCS Comparative Baseline. The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Glen Canyon Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 84-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 275-metric-ton decrease to a 96-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow category: For the Glen Canyon Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions results in a zero-metric-ton increase or decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 153-metric-ton decrease to a 160-metric-ton increase of CO_2e emissions.

The Average Flow Category (12.0–14.0 maf) 75th percentile variance results in no more than a 115-metric-ton increase in CO_2e for the Supply Driven (LB Pro Rata approach) and Supply Driven (LB Priority approach) Alternatives, which is equivalent to 23.3 gasoline-powered passenger vehicles driven for 1 year or 20.8 homes' electricity for 1 year.

Figure TA 7-15 in **TA 7**, Air Quality, shows the changes in CO_2e emissions due to a fluctuation of hydropower at Hoover Dam for each flow category and the alternatives. The Hoover Dam powerplant has 17 commercial generators with a maximum combined capacity of 2,074 MW. The powerplant requires a minimum Lake Mead elevation of 950 feet to produce power. At minimum power pool, the powerplant has an estimated capacity of 117 MW. At Lake Mead elevation of 1,035 feet, Hoover Dam's generating capacity is drastically reduced from 1,274 to 382 MW. In the Average Flow Category (12.0–14.0 maf), the No Action Alternative has the highest median with a 244-metric-ton increase in CO_2e emissions, and the largest interquartile range, with the 25th percentile at 52 metric tons and the 75th percentile at 456 metric tons of CO_2e. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives have medians showing a decrease in metric tons of CO_2e emissions. The Basic Coordination Alternative shows a median near zero metric tons of CO_2e emissions.

In the Critically Dry Flow Category (less than 10.0 maf), the medians for the No Action and Basic Coordination Alternatives display no change in CO_2e emissions relative to the CCS Comparative Baseline. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives all have medians showing a decrease in metric tons of CO_2e emissions, with the Supply Driven Alternative (LB Pro Rata approach) showing the largest decrease at 158 metric tons of CO_2e. The 25th to 75th percentiles across all alternatives span from a decrease of 577 metric tons to an increase of 105 metric tons of CO_2e emissions. The No Action Alternative has the smallest interquartile range, while the Supply Driven Alternative (LB Pro Rata approach) has the largest. The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Hoover Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 146-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 416-metric-ton decrease to a 75-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Hoover Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 115-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 374-metric-ton decrease to a zero-

metric-ton increase or decrease of CO_2e emissions. The Average Flow Category (12.0–14.0 maf) 75th percentile variance results in no more than a 456-metric-ton increase in CO_2e (under the No Action Alternative), which is equivalent to 90.3 gasoline-powered passenger vehicles driven for 1 year or 80.6 homes' electricity for 1 year.

Figure TA 7-16 in **TA 7**, Air Quality, shows the changes in CO_2e emissions due to a fluctuation of hydropower at Davis Dam for each flow category and the alternatives. In the Average Flow Category (12.0–14.0 maf), the Davis Dam alternatives exhibit varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 19-metric-ton decrease to a 40-metric-ton increase in CO_2e emissions. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives display similar medians ranging from 19 to 26 metric tons of CO_2e increase. The Representative Preferred Alternative and Basic Coordination Alternative medians are similar at around 10 metric tons of CO_2e increase, while the No Action Alternative has an 8 metric ton decrease in CO_2e emissions. The No Action Alternative is the only alternative with both a median and 25th percentile below zero. In the Critically Dry Flow Category (less than 10.0 maf), the median for the Basic Coordination Alternative displays very little change in CO_2e emissions, while the No Action Alternative shows a 4 metric ton decrease of CO_2e emissions relative to the CCS Comparative Baseline.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Davis Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 15-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 2-metric-ton increase to a 31-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the critically Dry Flow Category: For the Davis Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 14-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 5-metric-ton decrease to a 32-metric-ton increase of CO_2e emissions.

The Maximum Flexibility and Enhanced Coordination Alternatives stay equal to or above the CCS Comparative Baseline under each flow category, except the Wet Flow Category (16.0–31.0 maf). Therefore, they perform consistently the worst. The Average Flow Category (12.0–14.0 maf) 75th percentile variance results in no more than a 40-metric-ton increase in CO_2e (under the Enhanced Coordination Alternative), which is equivalent to 10 gasoline-powered passenger vehicles driven for 1 year or 9 homes' electricity for 1 year.

Figure TA 7-17 in **TA 7**, Air Quality, shows the changes in CO_2e emissions due to a fluctuation of hydropower at Parker Dam for each flow category and the alternatives. In the Average Flow Category (12.0–14.0 maf), Parker Dam alternatives exhibit varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 3-metric-ton decrease to a 25-metric-ton increase in CO_2e. Only the No Action and Basic Coordination Alternatives have medians that result in a decrease in CO_2e emissions; though, both are near a zero metric-ton change in CO_2e. The Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives have similar medians, ranging from near zero to a 5-metric-ton CO_2e increase. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have the highest medians, exceeding an increase of 14 metric tons of CO_2e emissions.

In the Critically Dry Flow Category (less than 10.0 maf), the medians for the No Action, Basic Coordination, Supply Driven (LB Priority approach), and Representative Preferred Alternatives are similar, displaying a decrease in CO_2e emissions ranging from 2 to nearly zero metric tons. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives all have medians showing an increase in metric tons of CO_2e emissions, with Enhanced Coordination showing the largest increase at 23 metric tons of CO_2e.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Parker Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 2-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a zero-metric-ton increase to a 5-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Parker Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 1-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 3-metric-ton decrease to a 6-metric-ton increase of CO_2e emissions.

The Enhanced Coordination Alternative is the most reliable because it stays equal to or above the CCS Comparative Baseline under each flow category; therefore, it performs consistently the worst. The Average Flow Category (12.0–14.0 maf) 75th percentile variance results in no more than a 25-metric-ton increase in CO_2e (under the Enhanced Coordination Alternative), which is equivalent to 5.4 gasoline-powered passenger vehicles driven for 1 year or 4.8 homes' electricity for 1 year.

Issue 3: How would climate trends affect lake reservoir elevations?

Climate trends affect lake reservoir elevations in several interrelated ways, driven largely by changes in temperature, precipitation patterns, and hydrologic cycles. Climate trends typically cause more variability and extremes in lake reservoir elevations, including lower lows during droughts, higher highs during storm events, and greater management complexity overall. The following are potential events that could be affected by climate trends and that would potentially affect reservoir elevations:

- Reduced snowpack and earlier snowmelt
- Increased evaporation rates from both lake surfaces and the surrounding land
- Changes in precipitation patterns
- Increased water demand

As discussed in Issue 2, climate events may affect hydropower. Any reduction in hydropower would require other power-generation sources to increase to compensate. The regional power mix can be analyzed to determine the region's potential capacity in order to replace hydropower with other alternative energy sources. Using available information from the Emissions and Generation Resource Integrated Database (eGRID) for the analysis area, **Table TA 7-22** in **TA 7**, Air Quality, shows that renewables, such as hydropower, biomass, wind, solar, and geothermal sources, are 42.8 percent of the Western Electricity Coordinating Council's resource mix, compared with nonrenewable resources, such as coal, oil, nuclear, and gas, totaling 57.3 percent. If the 19.8 percent hydropower is reduced, both renewable and nonrenewable resources would compensate. Other generation sources would likely replace lost hydropower and the mix of replacement sources can vary. However, a recent Argonne study shows that when there is a reduction in hydropower at Glen Canyon Powerplant, the

replacement generation is from mostly natural gas–fired generation (gas-combined cycle) and generation from gas combustion turbines, with a small portion also coming from coal-fired generation for 2024 through 2027 (Veselka et al. 2024). In addition, as climate trends are further observed and monitored, Reclamation has an opportunity to discuss any strategies to increase management flexibility, enhance climate adaptation planning, and improve infrastructure resilience.

Summary Comparison of Alternatives

For the Lake Powell WY maximum exposed shoreline area Average Flow Category (12.0–14.0 maf), the alternatives all have similar medians and small variabilities, except the Enhanced Coordination and Maximum Operational Flexibility Alternatives, which have the lowest median km^2 of exposed shoreline and the smallest variability. For the Lake Mead WY maximum exposed shoreline area Average Flow Category (12.0–14.0 maf), the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the lowest median shoreline exposure area. The CCS Comparative Baseline and No Action Alternative perform the worst and have the smallest variability. The Basic Coordination Alternative performs in the middle. These results are within the range analyzed across the other alternatives from this Final EIS.

For the full modeling period, the Lake Mead shoreline area robustness figure shows that the No Action Alternative performs the worst, with only 35 percent of the futures below 500 km^2 (123,553 acres) of shoreline area. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 80 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area. These same trends were seen for the 2027–2039, 2040–2049, and 2050–2060 modeling periods with higher percentages. For the 2027–2039 modeling period and 2040–2049 modeling period, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 88 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area.

The Lake Mead vulnerability plot shows that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions and less than 50 percent of the Drying with Variability traces include a driest 10-year average Lees Ferry annual flow this dry or drier. The CCS Comparative Baseline and No Action Alternative are the most vulnerable at 10-year average flows of 10.5 maf and 11.4 maf, respectively.

For the full modeling period, the Lake Powell shoreline area robustness figure shows that the No Action Alternative performs the worst, with only 16 percent of the futures below 500 km^2 (123,553 acres) of shoreline area. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 80 percent of the futures below 500 square km^2 (123,553 acres) of shoreline area. Similar trends were seen for the 2027–2039, though with higher percentages. The 2040–2049 and 2050–2060 modeling periods show that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the worst, then the No Action Alternative. For the 2027–2039, 2040–2049, and 2050–2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 87 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area.

The Lake Powell vulnerability plot shows that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are least vulnerable, as fewer than 25 percent of the Drying with Variability traces include a driest 10-year average Lees Ferry annual flow this dry or drier. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable under flow conditions associated with more than 75 percent of the Drying with Variability traces and are therefore the most vulnerable.

For the Lake Powell WY maximum shoreline dust emissions Average Flow Category (12.0–14.0 maf), several alternatives have similar medians, though Enhanced Coordination and Maximum Operational Flexibility Alternatives have the lowest median shoreline dust emissions and the smallest variability.

For the Lake Mead WY maximum shoreline dust emissions Average Flow Category (12.0–14.0 maf), the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the least shoreline dust emissions. The CCS Comparative Baseline and No Action Alternative perform the worst, with the highest shoreline dust emissions. The Basic Coordination Alternative performs in the middle.

For the full modeling period, the Lake Mead shoreline dust emissions robustness figure shows that the No Action Alternative performs the worst, with only 22 percent of the futures below 500 million kg (1,102 million pounds) of $PM_{2.5}$. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 76 percent and 69 percent, respectively, of the futures below 500 million kg (1,102 million pounds) of $PM_{2.5}$. These same trends were seen for the 2027–2039, 2040–2049, and 2050–2060 modeling periods with higher percentages, and the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 79 percent or more of the futures below 500 million kg of $PM_{2.5}$.

The Lake Mead vulnerability plot shows that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are least vulnerable, with vulnerability thresholds corresponding to conditions associated with roughly 25 to 50 percent of the Drying with Variability traces. The CCS Comparative Baseline and Basic Coordination Alternative are vulnerable to conditions associated with roughly 50 to 75 percent of the Drying with Variability traces. The No Action Alternative has a vulnerability threshold of 11.7 maf, which is similar to the driest observed 10-year period of 11.8 maf.

For the full modeling period, the Lake Powell shoreline dust emissions robustness figure shows that the No Action Alternative performs the worst, with only 10 percent of the futures below 450 million kg (992 million pounds) of $PM_{2.5}$. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 78 percent or more of the futures below 450 million kg of $PM_{2.5}$. These same trends were seen for the 2027–2039 with higher percentages. The 2040–2049 and 2050–2060 modeling periods show that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform the worst, then the No Action Alternative. For the 2027–2039, 2040–2049, and 2050–2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 84 percent or more of the futures below 450 million kg (992 million pounds) of $PM_{2.5}$.

The Lake Powell vulnerability plot shows that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to conditions associated with less than 25 percent of the Drying

with Variability traces. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have vulnerability thresholds corresponding to conditions associated with 75 to 100 percent of the Drying with Variability traces and are therefore the most vulnerable alternatives. The No Action Alternative has a vulnerability threshold of 12.2 maf, which is similar to the recently observed 10-year flow of 12.1 maf.

A general discussion of the effects of climate trends on lake reservoirs is discussed in **TA 7**, Air Quality; however, due to uncertainty, these effects cannot be determined for each specific alternative. In addition, **TA 3**, Hydrologic Resources, details the lake reservoir elevations for the flow categories and alternatives.

3.8 Biological Resources – Fish and Other Aquatic Species

3.8.1 Affected Environment

The affected environment consists of the Colorado River and its tributaries from Lake Powell downstream to the SIB. This area supports a diverse assemblage of aquatic organisms that form a complex food web that sustains both native and nonnative fish populations. Native fish include federally threatened and endangered species, range-wide conservation species (species under a multi-state conservation agreement), BLM sensitive species, and those covered under the LCR MSCP (Reclamation 2024c). Nonnative fish species, including cold-water and warmwater sportfish, are also present (see **Attachment 1** in **TA 8**, Biological Resources – Fish and Other Aquatic Species, for detailed life histories and distributions). River flow variations and dam operations, especially those related to Glen Canyon Dam, significantly influence aquatic habitats within the channel, shorelines, backwaters, and tributary mouths. Several invasive species have been inadvertently introduced, including quagga mussels (*Dreissena bugensis*), New Zealand mud snails (*Potamopyrgus antipodarum*), and various fish and aquatic plants (Reclamation 2024c).

Native Fish Species

Historically, the Colorado River supported 35 native fish species; of these, 26 were unique to the Basin (Miller 1955, 1958; Valdez and Muth 2005). Today, only eight native species remain within the analysis area: humpback chub, razorback sucker, Colorado pikeminnow, bonytail, bluehead sucker, flannelmouth sucker, desert pupfish, and speckled dace (FWS 2002; Valdez and Carothers 1998; Brockdorff 2022); see **Tables 8-1** and **8-2** in **Section TA 8.1**, Affected Environment. Of these species, the humpback chub, razorback sucker, Colorado pikeminnow, bonytail, and desert pupfish are ESA listed as endangered or threatened (Bestgen et al. 2020; Minckley et al. 2003).

Nonnative Fish Species

The presence of nonnative species has both beneficial and detrimental effects on the aquatic community. Although certain nonnative fish species support sport and recreational fisheries, they also pose substantial risks to native communities by increasing predation, competing for resources, and altering habitat conditions (NPS 2021a). High-risk species include smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), flathead catfish (*Pylodictis olivaris*), and brown trout (*Salmo trutta*). Other nonnatives, such as rainbow trout (*Oncorhynchus mykiss*), largemouth bass (*Micropterus salmoides*), green sunfish (*Lepomis cyanellus*), and striped bass (*Morone saxatilis*), are common and managed as sportfish

(see **Table TA 8-2** in **Section TA 8.1**, Affected Environment and **Attachment 1** in **TA 8**) (UDWR 2023).

Native and nonnative aquatic species are summarized across the following three Colorado River reaches: Lake Powell, Glen Canyon Dam to Pearce Ferry, and the LCR MSCP reaches (Lake Mead to Imperial Dam).

Lake Powell

Lake Powell supports 6 native fish species and at least 17 nonnative species (see **Table TA 8-2** in **Section TA 8.1**, Affected Environment) (Smith 2022). Native fish species include razorback sucker, bluehead sucker, flannelmouth sucker, and bonytail. Razorback suckers are present in the reservoir, and bonytail are stocked, with recent signs of reproduction. Colorado pikeminnow are rare, mainly occurring in inflows from the Colorado and San Juan Rivers. Flannelmouth and bluehead suckers are widespread, while speckled dace inhabit shorelines and tributaries.

Recent low water levels have created new riverine habitats, influencing fish movement and connectivity (Cathcart et al. 2018; Ahrens 2022). Water temperature and stratification dynamics affect habitat suitability and downstream releases from Glen Canyon Dam (Hueftle and Stevens 2001). Limnological data indicate changes in phytoplankton biomass and community composition, with potential implications for harmful algal blooms and water quality (Deemer et al. 2023). Invasive bivalves, including Asian clam (*Corbicula fluminea*) and quagga mussel, also alter plankton communities and threaten ecosystem health (USGS 2024).

Glen Canyon Dam to Pearce Ferry

This reach spans nearly 300 miles and is shaped by altered flow regimes and habitat diversity (Valdez and Ryel 1995). Native species include razorback sucker, humpback chub, bluehead sucker, flannelmouth sucker, and speckled dace (see **Table TA 8-2** in **Section TA 8.1**, Affected Environment) (NPS 2023b). Humpback chub also persists in tributaries such as the Little Colorado River and Havasu Creek. Currently, the Grand Canyon supports a native-dominated fish community, with the highest abundance of humpback chub anywhere in its current range and flourishing populations of bluehead and flannelmouth sucker. Nonnative species include rainbow trout, brown trout, bass, sunfish, catfish, and minnows (Shollenberger et al. 2025). Smallmouth bass and green sunfish recruitment are influenced by temperature and flow management (Reclamation 2025b). Invasive species, such as quagga mussels and New Zealand mud snails, are present but face environmental constraints (NPS 2015).

LCR MSCP Reaches (Lake Mead to Imperial Dam)

Lake Mead supports a unique, naturally recruiting population of razorback sucker and a diverse fish community, including humpback chub near the Colorado River confluence (see **Table TA 8-2** in **Section TA 8.1**) (Rogers et al. 2023). Downstream reaches (Lake Mohave, Lake Havasu, and Parker Strip) are managed for sportfish and native fish conservation, with stocking and augmentation programs for razorback sucker and bonytail (LCR MSCP 2024). Habitat creation, genetic monitoring, and pond rearing improve survival and recruitment (Kesner et al. 2012; Reap et al. 2023; Bestgen et al. 2020). Invasive species, including quagga mussel, crayfish, Asian clam, and snails, continue to threaten water quality and native biota (USGS 2025c).

3.8.2 Environmental Consequences

Methodology

DMDU modeling was used to evaluate potential Colorado River management strategies across a wide range of plausible hydrologic futures. The analysis compared five alternatives, a Preferred Alternative, and a Continued Current Strategies baseline representing different river flow and reservoir management approaches. For the Final EIS, modeling used 400 hydrologic traces under a Dry initial condition (with Mid and Wet conditions removed), and analysis of the Preferred Alternative focuses on the first 10 years of impacts due to its 10-year implementation period. DMDU evaluates how alternatives may affect aquatic habitats, water quality, and fish populations, and measures performance using robustness scores that indicate how often resource objectives are met across modeled futures. Results are summarized using visual tools, including conditional box plots that show resource responses under different hydrologic conditions, robustness heat maps that compare long-term performance across scenarios, and vulnerability bar plots that identify the hydrologic conditions under which alternatives fail to meet thresholds. Together, these tools provide a comparative framework for understanding potential system outcomes and the relative resilience of alternatives under uncertain future conditions. Additional issue-specific methodology is described in **Section TA 8.2.1**, Methodology, in **TA 8**, Biological Resources – Fish and Other Aquatic Species.

Impact Analysis Area

The impact analysis area includes the Colorado River corridor from the full-pool elevation of Lake Powell downstream to the SIB, including various habitats and reaches described in the analysis area (see **Section 3.2**).

Assumptions

Modifications in the quantity, timing, temperature, and quality of water released from Glen Canyon Dam and Hoover Dam through the lower Colorado River are expected to influence fish habitats, distributions, and population abundances; this is because changes in flow can alter available habitat and affect species' numbers. Reduced flows are likely to affect backwaters and riverine habitats that support native fish; reduced flows may also affect known spawning sites for razorback sucker. Reservoir conditions are also considered, particularly the potential for low Lake Powell elevations (below 3,570 ft) to increase entrainment of smallmouth bass and other nonnative fishes, which could negatively affect humpback chub and other native species in the action area. The analyses use models such as CRSS and the smallmouth bass population model developed in collaboration with various agencies. For efficiency of analysis, some LCR MSCP reaches are combined for analysis where special status species, habitat conditions, operations, and management are similar. Ongoing fisheries management practices by agencies within the Colorado River Basin are expected to remain consistent into the future.

Impact Indicators

Key impact indicators included the abundance and location of razorback sucker larvae, elevation thresholds where spawning habitats may become limited, and annual monitoring data for sportfish catches. Additional indicators were habitat availability and abundance of native fish species by life stage, changes in backwater area at different flow stages, and shifts in the distribution and abundance

of Colorado pikeminnow, razorback sucker, and humpback chub with expanded inflows. The analyses also considered electrofishing and angler catch rates for rainbow trout and brown trout in the Lees Ferry sub-reach, changes in fish habitat and population numbers based on dam releases and flow conditions, and the suitability and area of razorback sucker spawning sites at different flow stages.

Other indicators included changes to Colorado pikeminnow and razorback sucker critical habitat in the Lake Powell inflows, changes to razorback sucker critical habitat in Lake Mead, increased smallmouth bass escapement through Glen Canyon Dam, downstream distribution, salinity concentration changes, and the effects of lower reservoir elevations on shoreline spawning and nursery habitat for razorback sucker. Maintaining reservoir elevation to protect the power pool at Lake Powell (above 3,490 feet) and Lake Mead (above 1,000 feet) and to preserve the Piute Farms Rapid (above 3,666.5 feet) and the Pearce Ferry Rapid (above 1,090 feet) was also important. The analyses further considered reduced abundance and distribution of fish species, water quality impacts, and reduced wetland area and river inflow habitat.

Issue 1: Lower reservoir elevations have reduced lake habitat and extended the inflows of the Colorado River and San Juan River by approximately 35 miles each. How will changes in flow affect the quantity and quality of lake, wetland, and riverine inflow habitats?

Recent declines in Lake Powell's elevation have altered aquatic habitat conditions, affecting ESA-listed native fish and other aquatic species in the Colorado River Basin. Lower reservoir elevations have reduced traditional lake environments while expanding riverine inflow reaches in the Colorado and San Juan Rivers. This change increases the length of exposed riverine habitat, which benefits endangered species such as Colorado pikeminnow and razorback sucker that prefer flowing river conditions and whose designated critical habitat occurs in these inflow areas (see **Tables TA 8-3** and **TA 8-4** in **Section TA 8.2.2**, Environmental Consequences, Issue 1). The most important threat associated with reservoir operations is the establishment and spread of nonnative piscivorous fish, particularly smallmouth bass, which can increase predation and competition pressures on native species such as humpback chub and other fishes targeted for recovery in the Colorado River Basin. Reservoir elevation is a key driver of these risks because it affects the likelihood that smallmouth bass are entrained through Glen Canyon Dam, the effectiveness of Piute Farms Waterfall on the San Juan River as a barrier to upstream fish movement, the extent of riverine critical habitat in the Colorado and San Juan River inflows, and the availability of shoreline habitat that favors nonnative fish reproduction. Accordingly, four primary impact indicators were evaluated: (1) smallmouth bass entrainment through Glen Canyon Dam and subsequent downstream expansion, (2) maintaining Lake Powell elevations below 3,666.5 feet to preserve Piute Farms Waterfall as a barrier to upstream movement of nonnative fish, (3) the extent of riverine critical habitat for Colorado pikeminnow and razorback sucker in the Colorado and San Juan River inflows, and (4) the amount of exposed shoreline habitat favorable for smallmouth bass spawning and recruitment.

Lake Powell elevation influences the extent of riverine critical habitat for Colorado pikeminnow and razorback sucker in the Colorado and San Juan River inflows. When the reservoir rises above approximately 3,598 feet in the Colorado River inflow and 3,600 feet in the San Juan River inflow, portions of designated critical habitat become inundated and converted from flowing river habitat to reservoir conditions (see **Tables TA 8-3** and **TA 8-4**). **Figures TA 8-1** and **TA 8-3** evaluate the robustness of each alternative in maintaining lake elevations below these thresholds and preserving

riverine habitat, while **Figures TA 8-2** and **TA 8-4** illustrate the hydrologic conditions under which alternatives may exceed these thresholds. Modeling results indicate that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most effective at maintaining elevations below these thresholds and protecting riverine habitat and slightly outperforms the CCS Comparative Baseline. In contrast, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust at maintaining these conditions because they more frequently produce higher Lake Powell elevations, which inundate riverine habitat. The Representative Preferred Alternative performs moderately across these indicators, maintaining elevations below these thresholds in about 40 percent of futures during the initial implementation period.

Reservoir elevation also determines whether Piute Farms Waterfall continues to function as a barrier to fish movement in the lower San Juan River. When Lake Powell elevations exceed approximately 3,666.5 feet, the waterfall becomes inundated, and fish from the reservoir, including predatory nonnative species, can move upstream into riverine habitats. **Figure TA 8-5** evaluates the robustness of each alternative in maintaining elevations below this threshold, while **Figure TA 8-6** identifies the flow conditions that could result in elevations exceeding the threshold. Modeling results show that maintaining this barrier throughout the full modeling period is difficult under all alternatives; however, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs best, followed by the CCS Comparative Baseline. The Representative Preferred Alternative maintains the barrier in approximately one third of futures over the full modeling period and in more than half of futures during the initial implementation period. Although the waterfall also prevents native fish such as Colorado pikeminnow and razorback sucker from returning upstream to historic habitats, maintaining the barrier is generally considered beneficial because it prevents upstream expansion of predatory nonnative fish.

Reservoir elevation affects the availability and types of shoreline habitat around Lake Powell, which in turn influences fish community composition and recreational fisheries. **Table TA 8-5** quantifies how shoreline habitat area changes with reservoir elevation. Higher reservoir levels inundate broad cobble, gravel, and vegetated shorelines that tend to support sportfish such as largemouth bass, bluegill, and crappie, whereas lower reservoir levels expose steep cliff and rockfall habitats that favor smallmouth bass spawning, growth, and recruitment. Modeling results indicate that most alternatives would increase the amount of exposed shoreline habitat relative to the CCS Comparative Baseline (see **Figure TA 3-6** in **TA 3**, Hydrologic Resources), conditions that may favor smallmouth bass population growth and increase the risk that individuals are entrained downstream, potentially increasing predation pressure on native fish populations below Glen Canyon Dam.

Maintaining October 1 Lake Powell elevations above approximately 3,570 feet reduces the likelihood that smallmouth bass occupy forebay areas where entrainment through Glen Canyon Dam is likely. **Figure TA 8-7** evaluates the robustness of each alternative in maintaining October 1 elevations above this threshold, while **Figure TA 8-8** shows the hydrologic conditions under which alternatives are vulnerable to elevations falling below the threshold. Modeling results indicate that the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best in reducing entrainment risk. The remaining action alternatives and the CCS Comparative Baseline perform substantially worse. The Representative Preferred Alternative performs at an intermediate level, maintaining the elevation threshold in about 42 percent of futures during the first implementation period.

Lake Powell reservoir elevations influence native fish conservation outcomes through multiple interacting mechanisms, including nonnative fish establishment, riverine habitat availability, fish passage barriers, and shoreline habitat conditions. Different operational alternatives, therefore, involve trade-offs among reducing risks from nonnative fish, maintaining critical riverine habitat for endangered fish, preserving natural barriers to upstream fish movement, and sustaining reservoir fisheries under uncertain future hydrologic conditions.

Issue 2: Changes in water quantity, release timing, temperature, and quality from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry.

The reach of the Colorado River from Glen Canyon Dam to Lake Mead has experienced substantial ecological change due to long-term modifications in flow magnitude, timing, temperature, and water quality associated with dam operations. These changes have influenced habitat conditions and fish populations throughout the Grand Canyon, affecting ESA-listed species such as humpback chub and razorback sucker, as well as other native species and sportfish, including flannelmouth sucker, bluehead sucker, and rainbow trout. Of particular concern is the potential establishment of nonnative piscivorous fish, especially smallmouth bass, which may be entrained through Glen Canyon Dam when Lake Powell elevations decline, and the warm epilimnion aligns more closely with dam penstocks. Entrainment modeling indicates that propagule pressure increases substantially when reservoir elevations fall below approximately 3,530 feet and persists until elevations fall below the minimum power pool of 3,490 feet, after which releases through river outlet works reduce invasion risk (Eppehimer et al. 2025). Maintaining Lake Powell elevations above approximately 3,570 feet at the start of the year substantially reduces the likelihood of entraining smallmouth bass and other undesirable nonnative species. Warmer releases associated with lower reservoir levels may also increase downstream water temperatures, potentially facilitating reproduction and establishment of warmwater nonnative fish that could increase predation and competition pressures on native species.

A combination of hydrologic, water quality, temperature, and biological indicators was used to evaluate these risks. River flows from CRSS were used to characterize hydrologic conditions affecting aquatic habitat, while a smallmouth bass population model integrating reservoir elevation, water temperature, inflow volumes, and outflows was used to estimate propagule pressure at Glen Canyon Dam and population growth rates (lambda) at several locations downstream, including Lees Ferry, the Little Colorado River confluence (RM 61), Havasu Creek confluence (RM 156), and Pearce Ferry (RM 281). Lambda values greater than 1 indicate increasing populations, while values less than 1 indicate declining populations. Key water temperature thresholds used in the analysis included 12 °C (53.6 °F), which supports humpback chub growth; 16 °C (60.8 °F), which promotes spawning of both humpback chub and smallmouth bass; and 20 °C (68 °F), which can cause thermal stress or mortality for trout species.

Water quality conditions were evaluated using modeled dissolved oxygen concentrations in dam releases (see **Figures TA 6-11** through **TA 6-14** in **TA 6**). Results indicate that minimum annual dissolved oxygen concentrations generally remain between approximately 4 and 7 mg/L under average hydrologic conditions but decrease under drier scenarios. Robustness analysis (**Figure TA 6-12**) shows that the Enhanced Coordination and Maximum Operational Flexibility alternatives are most effective at maintaining dissolved oxygen above the hypoxic threshold of 2 mg/L in at least 90 percent of years across modeled futures. Vulnerability analysis (**Figure TA 6-14**) indicates that the CCS Comparative

Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are more likely to produce undesirable conditions under hydrologic scenarios represented in the Drying with Variability ensemble, whereas the Enhanced Coordination and Maximum Operational Flexibility alternatives remain resilient under most modeled drought conditions.

Water temperatures important to native fish habitat were evaluated using historical monitoring data and modeled scenarios within the DMDU framework. Hourly temperature data from monitoring stations near the Little Colorado River and Diamond Creek for water years 2008 to 2025 were used to calculate the number of days per year exceeding biologically relevant thresholds of 12 °C and 16 °C (53.6 °F and 60.8 °F). These thresholds represent conditions that support humpback chub growth (12 °C [53.6 °F]) and spawning (16 °C [60.8 °F]). Historical patterns showed that most years experienced at least 110 days above these thresholds, which was adopted as a benchmark for thermally suitable conditions. Model outputs were then summarized using heatmaps and boxplots to evaluate how management alternatives influence temperature regimes along the river corridor from Lees Ferry to Pearce Ferry and how those conditions affect native fish, trout species, and nonnative predators such as smallmouth bass.

At Lees Ferry, temperature outcomes vary among alternatives and hydrologic conditions (**Figure TA 8-9**). Exceeding 12 °C (53.6 °F) generally promotes humpback chub growth, while temperatures above 16 °C (60.8 °F) promote smallmouth bass spawning and those above 20 °C (68 °F) can reduce rainbow trout survival. Under average hydrologic conditions, most alternatives produce similar temperature patterns, although the Enhanced Coordination and Maximum Operational Flexibility Alternatives result in fewer days exceeding the higher thresholds because they maintain cooler dam releases. Robustness analysis (**Figure TA 8-10**) indicates that the Enhanced Coordination Alternative performs best in maintaining temperatures below 20 °C (68 °F), followed by the Maximum Operational Flexibility Alternative. Vulnerability analysis (**Figure TA 8-11**) shows that most alternatives become susceptible to temperatures above 20 °C (68 °F) during extended drought conditions. The Representative Preferred Alternative performs moderately, meeting the preferred temperature threshold in fewer futures than the highest performing alternatives.

At the Little Colorado River confluence, water temperatures are generally warmer and more conducive to native fish growth than at Lees Ferry (**Figure TA 8-12**). Exceeding the 12 °C (53.6 °F) threshold promotes humpback chub growth, while exceeding 16 °C (60.8 °F) supports spawning but may also favor smallmouth bass. Robustness analysis (**Figure TA 8-13**) shows that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs best at achieving the preferred threshold for humpback chub growth, while the Enhanced Coordination and Maximum Operational Flexibility alternatives perform worst because they maintain cooler water temperatures. However, analysis of the 16 °C (60.8 °F) spawning threshold (**Figure TA 8-14**) indicates that all alternatives perform poorly at achieving sustained mainstem spawning conditions for humpback chub. This result suggests that humpback chub spawning will likely remain concentrated in the Little Colorado River tributary rather than the mainstem.

Farther downstream at the Havasu Creek confluence, temperature conditions are generally warm enough to support humpback chub growth across most alternatives (**Figure TA 8-15**). Robustness results indicate that nearly all alternatives meet the threshold of at least 110 days above 12 °C (53.6 °F) in most futures (**Figure TA 8-16**). However, achieving temperatures above 16 °C (60.8 °F) for

extended periods, which could support humpback chub spawning but also promote smallmouth bass reproduction, is less common (**Figure TA 8-17**). The Enhanced Coordination and Maximum Operational Flexibility Alternatives produce fewer days above this threshold, limiting both native and nonnative spawning potential. The Representative Preferred Alternative performs strongly for the growth threshold but more moderately for spawning related temperature thresholds.

At Pearce Ferry, water temperatures are influenced more strongly by ambient air temperatures than by dam releases because of the long distance downstream from Glen Canyon Dam (**Figure TA 8-18**). As a result, differences among alternatives are smaller. All alternatives consistently exceed the 12 °C (53.6 °F) threshold needed for humpback chub growth (**Figure TA 8-19**), but conditions conducive to spawning (temperatures above 16 °C [60.8 °F]) vary more widely (**Figure TA 8-20**). Alternatives that maintain cooler upstream release temperatures, particularly the Enhanced Coordination and Maximum Operational Flexibility Alternatives, produce fewer days above the spawning threshold, which may reduce smallmouth bass reproduction but also limit opportunities for humpback chub spawning in the mainstem.

Temperature outcomes also influence smallmouth bass population growth and entrainment risk. Modeling of smallmouth bass population growth rates (lambda) indicates that the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best at maintaining lambda below 1, indicating declining populations if established (**Figure TA 8-21**). The No Action Alternative and CCS Comparative Baseline perform worst in this regard. Vulnerability analysis (**Figure TA 8-22**) shows that prolonged dry hydrologic conditions increase the likelihood that smallmouth bass populations could grow.

Finally, entrainment modeling evaluates the number of smallmouth bass that may pass through Glen Canyon Dam and survive downstream (**Figure TA 8-23**). The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best at limiting entrainment, whereas the other alternatives perform substantially worse. Vulnerability analysis (**Figure TA 8-24**) indicates that all alternatives could experience elevated entrainment during dry hydrologic conditions because low Lake Powell elevations align warm surface waters, where smallmouth bass reside, with dam penstocks. Overall, alternatives that maintain higher reservoir elevations and cooler release temperatures generally reduce smallmouth bass invasion risk but may also limit thermal conditions favorable for native fish growth and spawning, illustrating a key management tradeoff in temperature management below Glen Canyon Dam.

Overall, reservoir elevation, dam release temperature, and hydrologic variability strongly influence aquatic habitat conditions and fish population dynamics downstream of Glen Canyon Dam. Alternatives that maintain higher Lake Powell elevations generally produce cooler release temperatures, lower entrainment risk, and reduced growth in the smallmouth bass population, which benefits trout survival and helps limit the establishment of nonnative fish. However, these cooler conditions may also limit thermal opportunities for humpback chub growth and mainstem spawning. Conversely, alternatives that allow warmer water conditions may benefit native fish growth but also increase the risk of smallmouth bass reproduction and establishment. These results illustrate the tradeoffs among management alternatives in balancing native fish recovery, control of nonnative predators, and maintenance of recreational fisheries under uncertain future hydrologic conditions.

Issue 3: Lower reservoir elevations have reduced lake habitat and extended river inflows, including about 30 miles on the Colorado River and 20 miles on the Virgin River, with similar extensions observed at Las Vegas Bay, Echo Bay, and other locations. How will these inflow changes affect the quantity and quality of lake, wetland, and riverine inflow habitats?

The Lower Colorado River Basin from Lake Mead to the SIB has experienced ecological changes driven by fluctuations in reservoir elevations and tributary inflows, which affect the quantity and quality of aquatic habitat for native, nonnative, and recreationally important fish species. Lower Lake Mead elevations reduce littoral shoreline habitat used by sportfish and razorback sucker, while simultaneously extending riverine inflow habitats along the Colorado River, Virgin River, and other tributaries. These changes may alter the extent of designated critical habitat for razorback sucker and influence the distribution and movement of native fishes such as humpback chub and razorback sucker. Reservoir elevation also affects fish passage at Pearce Ferry Rapid, which functions as a natural barrier to upstream fish movement under lower lake levels but becomes inundated at elevations above approximately 1,090 feet. When the rapid is submerged, both native and nonnative fish may move upstream from Lake Mead into the Grand Canyon. Conversely, elevations below approximately 1,000 feet would compromise hydropower generation. To evaluate these conditions, the analysis considered indicators including monitoring data on sportfish catch, shifts in native fish distribution and abundance, and changes in the availability and quality of shoreline and inflow spawning habitats. Monitoring datasets from Arizona Game and Fish Department (AZGFD), Nevada Department of Wildlife (NDOW), and the LCR MSCP were integrated with DMDU modeling results to evaluate how alternative management strategies may affect reservoir elevations, aquatic habitats, and fish community dynamics.

Two key elevation thresholds were evaluated in the analysis. The first threshold is Lake Mead elevation of 1,090 feet, above which Pearce Ferry Rapid becomes inundated and no longer functions as a barrier to upstream fish passage. Robustness analysis (**Figure TA 8-25**) evaluates the percentage of modeled futures in which Lake Mead remains below 1,090 feet for at least 90 percent of months, a threshold based on recent historical conditions, during which the reservoir remained below this elevation approximately 94 percent of the time between 2016 and 2026. Results show that the No Action Alternative performs best, followed by the CCS Comparative Baseline. Among action alternatives, the Basic Coordination Alternative performs best. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives perform the worst. The Representative Preferred Alternative meets the threshold in 20 percent of futures over the full modeling period and in approximately 39 percent of futures during the first implementation decade (2027–2039). Vulnerability analysis (**Figure TA 8-26**) indicates that several alternatives, including the Representative Preferred Alternative, become vulnerable to elevations exceeding 1,090 feet under relatively moderate 10-year average flows of approximately 12.4 maf or wetter, conditions that occur in most traces of the Drying with Variability ensemble. In contrast, the No Action Alternative and CCS Comparative Baseline are less vulnerable and would generally exceed the threshold only under wetter conditions.

The analysis also evaluated the potential for lake elevations to fall below the lowest elevation observed during the recent historical period (1,040.92 feet in July 2022), which serves as a proxy for maintaining shoreline habitats that have historically supported the current fish community. Robustness analysis

(**Figure TA 8-27**) evaluates the percent of modeled futures in which Lake Mead remains at or above this elevation for at least 90 percent of months. Results show that the No Action Alternative performs worst, while the CCS Comparative Baseline and Basic Coordination Alternatives perform modestly better. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives perform substantially better with the Supply Driven Alternative (LB Pro Rata approach) performing best. The Representative Preferred Alternative meets this threshold in 26 percent of futures across the full modeling period, although performance is lower during the initial decade (17 percent). Vulnerability analysis (**Figure TA 8-28**) indicates that most alternatives become vulnerable to elevations falling below 1,040.92 feet under 10-year average flows between approximately 10.9 and 11.7 maf or drier; conditions that are comparable to or slightly drier than the historically observed minimum 10-year average of 11.8 maf.

Overall, reservoir elevation strongly influences aquatic habitat availability and fish community dynamics in Lake Mead and downstream reaches. Alternatives that maintain lower reservoir elevations are more effective at sustaining Pearce Ferry Rapid as a barrier to upstream fish movement, which may help limit the spread of nonnative species into the Grand Canyon but also restrict the movement of native fishes such as the razorback sucker. Conversely, alternatives that maintain higher lake levels improve the likelihood of sustaining shoreline spawning and nursery habitats that support the existing Lake Mead fish community, but increase the potential for fish passage across Pearce Ferry Rapid. If reservoir elevations remain within the historical range observed between 2008 and 2026, the current fish assemblage and habitat conditions are expected to persist. However, prolonged periods outside this historical range, particularly sustained low-elevation conditions, may reduce shoreline spawning habitats and increase ecological stress for aquatic species in the Lake Mead ecosystem.

Issue 4: How would modifications in water quantity, timing, temperature, and quality released from Hoover Dam affect the lower Colorado River, including LCR MSCP reaches 2 through 6 (Hoover Dam to Davis Dam and Lake Mohave, Davis Dam to Parker Dam and Lake Havasu, Parker Dam to Cibola Gage, Cibola Gage to Imperial Dam and Imperial Reservoir, and Imperial Dam to the NIB)?

Hoover Dam operations may influence aquatic habitats and fish populations in the Lower Colorado River from Hoover Dam downstream to Imperial Dam, including reaches managed under the LCR MSCP. Although ESA mitigation measures are already in place through previous consultations, this EIS assesses how different operational alternatives may affect river flows, timing, temperature, and water quality under NEPA. Changes in these factors could influence habitats and population dynamics of endangered species such as razorback sucker and bonytail, as well as other native fishes, including flannelmouth sucker and desert pupfish. Modified flow regimes may affect the extent of backwater and riverine habitats, the location and suitability of razorback sucker spawning areas, and the stability of constructed desert pupfish refuge ponds if flows fall outside historical bounds. Reduced flows could also allow predatory nonnative fish, such as flathead catfish, to expand upstream from the Cibola gage toward Imperial Dam, increasing the predation risk to native fishes. The analysis relies on monitoring data from agencies including AZGFD, NDOW, the California Department of Fish and Wildlife, Reclamation, the LCR MSCP, and U.S. Fish and Wildlife Service (FWS), with the assumption that fisheries management practices, such as stocking of listed species, continue as they have since 2008.

A primary indicator evaluated in the analysis is whether monthly releases from Hoover Dam remain within the range observed during the Interim Guidelines period (2008–2025), representing the recent historical flow regime to which aquatic communities have experienced. Robustness analysis (**Figure TA 8-29**) evaluates the percent of modeled futures in which releases remain within this historical range for 100 percent of months. Results show that the No Action Alternative, CCS Comparative Baseline, and Basic Coordination Alternative are the most robust. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs moderately worse, while the Enhanced Coordination Alternative performs similarly. The Maximum Operational Flexibility Alternative performs the worst. Despite these differences, all alternatives maintain releases within the historical range in more than 92 percent of months across the full modeling period. Decadal analysis shows similar rankings, with the No Action, CCS Comparative Baseline, and Basic Coordination Alternatives meeting the threshold in roughly 75–88 percent of futures, while other alternatives perform somewhat lower but still maintain releases within historical bounds for more than 90 percent of months.

Additional analysis of monthly release magnitudes (**Figure TA 8-30**) compares annual minimum and maximum releases across hydrologic conditions. Under Wet Flow categories, most alternatives produce similar distributions of minimum and maximum releases, indicating comparable operational responses during high inflow periods. However, the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) tend to produce higher annual maximum monthly releases than other alternatives. As hydrologic conditions become drier, differences among alternatives become more apparent. The No Action Alternative, Basic Coordination Alternative, and CCS Comparative Baseline maintain relatively higher minimum releases during critically dry conditions, indicating continued higher downstream flows even during drought. In contrast, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) generally result in lower minimum releases during dry periods because these alternatives implement larger shortage reductions to conserve storage in Lake Mead. Even under critically dry conditions, minimum monthly releases remain above the historical reference threshold of 220 kaf in approximately 90 percent or more years for most alternatives, except the Maximum Operational Flexibility Alternative, which falls below that threshold more frequently. Results for the Representative Preferred Alternative fall within the range observed across other alternatives, with median annual minimum and maximum releases remaining within historical bounds under both dry and critically dry conditions.

Operational differences among alternatives produce only modest changes in Hoover Dam release patterns relative to the historical flow regime experienced between 2008 and 2025. Alternatives that maintain higher release volumes during drought conditions, such as the No Action and Basic Coordination Alternatives, may accelerate declines in Lake Mead storage but maintain relatively stable downstream flows. Alternatives that reduce releases during drought conditions may help maintain reservoir elevations while still providing flows within the historical range experienced by aquatic species. Because downstream impoundments such as Lake Mohave and Lake Havasu operate under guide curves that maintain relatively stable elevations across alternatives, and because modeled releases remain largely within historical ranges, aquatic habitats within the LCR MSCP reaches are expected to remain generally similar to recent historical conditions. Under these circumstances, fish community composition and population dynamics downstream of Hoover Dam would likely remain comparable to those observed during the 2008–2025 period, assuming continued fisheries management and habitat restoration efforts.

Summary Comparison of Alternatives

The analysis compares several proposed alternatives for the Colorado River downstream of Glen Canyon Dam using hydrologic modeling, ecological indicators, temperature thresholds, and assessments of ecosystem vulnerability and resilience. A full summary of those findings can be found in **Figure TA 8-31** in **Section TA 8.2.6**, Summary Comparison of Alternatives. Key findings show that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are most robust in maintaining cooler water temperatures, maintaining higher dissolved oxygen levels, and controlling nonnative species like smallmouth bass. However, they may restrict native fish spawning and growth. In contrast, the No Action Alternative and the CCS Comparative Baseline better preserve riverine habitats above Lake Powell and prevent upstream movement of nonnative fish from Lake Powell and Lake Mead; this would benefit endangered species such as Colorado pikeminnow and razorback sucker but reduce lake habitat for sportfish. For Lake Mead and downstream habitats, the No Action Alternative and the CCS Comparative Baseline maintain lower lake elevations that help contain nonnative fish; however, they may also limit native fish access to new habitats. Most alternatives support stable flows and fish communities downstream of Hoover Dam, though the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are less robust in maintaining desirable release patterns. The Representative Preferred Alternative typically falls within the middle of the range of outcomes across issues. Each alternative involves trade-offs between supporting native endangered species, controlling nonnative fish, and maintaining recreational fisheries.

3.9 Vegetation Including Special Status Species

3.9.1 Affected Environment

This analysis categorizes vegetation into marsh, woody riparian, and upland habitat types (collectively referred to as terrestrial habitats) throughout the analysis area, which includes Lake Powell, Glen Canyon Dam to Lake Mead, Lake Mead, and Hoover Dam to the SIB. For additional information on the affected environment, including a list of special status species, please reference **TA 9**, Vegetation Including Special Status Species, and **Attachment 1**, Special Status Plant Species, in **TA 9**. **Table TA 9-1** in **Section TA 9.1**, Affected Environment, provides the approximate acreages of marsh, woody riparian, and upland habitats by reach. Wetlands in the analysis area are typically characterized by marsh habitat, but could also occur in woody riparian habitats.

Marsh habitats occur in areas that are consistently flooded and are typically found in the transition zone between open water and upland ecosystems. Marsh vegetation is sensitive to drought on short timescales, seasonally to annually, and has been found to decrease in cover, species diversity, and productivity when water availability shifts from perennial to intermittent (Stromberg et al. 2005, 2007; Friedman et al. 2022). Woody riparian habitats occur where water is consistently available and periodic flooding occurs. Woody riparian vegetation typically has deeper root systems capable of accessing alluvial groundwater and is not dependent on surface water flows (Stromberg et al. 2013). This vegetation type is sensitive to drought on longer timescales, on an annual to decadal scale, depending on the species (Shafroth et al. 2002). Upland habitats occur in areas without consistent water availability, where vegetation depends on precipitation.

Lake Powell

Short-term and long-term fluctuating water elevations influence Lake Powell's shoreline vegetation. The median annual water elevation fluctuation during the 2007 Interim Guidelines period (between 2008 and 2025) was 31.45 feet (see **Figure TA 9-1** in **Section TA 9.1**, Affected Environment). The drought-induced drawdown of Lake Powell since 2011 has reduced the lake's perimeter and exposed approximately 59,000 acres of formerly submerged land (Root and Jones 2022). Recently exposed sites below full pool of Lake Powell shows a higher percentage and cover of nonnative species, with prickly Russian thistle (*Salsola tragus*) being extremely abundant (Arens 2023). However, native shrubs are outcompeting nonnative plants on sites that have been exposed for more than 3 years; these shrubs are providing diverse ecosystems, including hanging gardens and cryptobiotic crusts, where natural flow patterns are reestablishing (Arens 2023, NPS 2026). As water levels continue to drop, newly established vegetation may begin to decline (Kasprak et al. 2026). Two special status plant species are present in the Lake Powell reach and could be affected by operations (**Attachment 1** in **TA 9**, Vegetation Including Special Status Species).

Glen Canyon Dam to Lake Mead

Marsh, woody riparian, and upland habitats from Glen Canyon Dam to Lake Mead are influenced by the peak magnitudes, daily fluctuations, and seasonal patterns of river flows. Most evidence indicates that vegetation composition, structure, distribution, and function are closely tied to ongoing Glen Canyon Dam operations (Reclamation 2016; Palmquist et al. 2023). Marsh and woody riparian vegetation have expanded in this reach since Glen Canyon Dam was completed in 1963 (Sankey et al. 2015). The greatest area of vegetation expansion between 2002 and 2013 was woody riparian vegetation on sandbars in the active channel (Durning et al. 2021). The availability of water at low river elevations from consistent base flows can promote vegetation establishment, whereas prolonged periods of peak flow may inhibit vegetation establishment. When inundation frequency increases by 5 percent or more, vegetation expansion was unlikely to occur (Sankey et al. 2015).

Twenty special status plant species are present in the Grand Canyon to Lake Mead reach and could be affected by operations (**Attachment 1** in **TA 9**, Vegetation Including Special Status Species).

Lake Mead

Similar to Lake Powell, short- and long-term fluctuations in water elevation affect Lake Mead's shoreline vegetation. The median annual water elevation fluctuation between 2008 and 2025 was 16.19 feet (see **Figure TA 9-3** in **Section TA 9.1**). The drawdown of Lake Mead from 1998 to 2011 reduced the lake's perimeter by more than 400 kilometers (250 miles) and exposed more than 61,776 acres of formerly submerged land (Engel et al. 2014). Long-term fluctuations allow the establishment of woody riparian vegetation, including the nonnative and invasive tree tamarisk (*Tamarix* spp.); however, as lake levels continue to fall, tamarisk may begin to show drought stress and mortality when water levels fall below their roots.

Overall, native species cover has been found to be greatest on surfaces that have been exposed for a longer period of time (Engel et al. 2014). Native vegetation at Lake Mead has been positively influenced by defoliation from the tamarisk leaf beetle (*Diorhabda* spp.) (beetle). Twenty-one special status plant species are present in the Lake Mead reach and could be affected by operations (**Attachment 1** in **TA 9**, Vegetation Including Special Status Species).

Hoover Dam to the Southerly International Boundary (SIB)

The LCR MSCP planning area identifies 14 land cover types, including five woody riparian types that are divided into multiple structural types. The marsh land cover type is divided into seven compositional types based on plant composition and vegetation structure (Reclamation 2004; see **Table TA 9-2** in **Section TA 9.1**). Since the beetle's release in 2006, its range has expanded downstream from Lake Mead along the lower Colorado River; by 2019, large beetle populations were detected along the Imperial stretch of the lower Colorado River. In 2020, beetles were present, and defoliation was documented in or around all LCR MSCP study areas (Reclamation 2021). In 2024, beetles were documented to the SIB (McLeod and Pellegrini 2021; Mahoney et. al 2022; RiversEdge West 2025).

In 2024, Reclamation contracted RiverRestoration.Org to map backwater areas (water, marsh, and non-marsh) in the LCR MSCP planning area and to conduct a change analysis between the 2024 effort and a 2000 backwater mapping effort (RiverRestoration.Org 2025). The study found an overall decrease in marsh area between Davis Dam and Morelos Dam from 2000 to 2024. Nine special status plant species are present in the Hoover Dam to SIB reach and could be influenced by operations (**Attachment 1** in **TA 9**, Vegetation Including Special Status Species).

3.9.2 Environmental Consequences

Figures referenced in this section and a description of how to interpret the results of the analysis are provided in **Section TA 9.2**.

Methodology

There are no long-term vegetation monitoring datasets available for Lake Powell, Lake Mead, or Hoover Dam to the SIB that would support quantitative habitat modeling, as was done for the Glen Canyon Dam to Lake Mead section; therefore, a qualitative approach was used to determine the predicted differences in marsh and woody riparian vegetation among the alternatives. As noted in **Section 3.9.1**, Affected Environment, marsh and woody riparian vegetation are affected by water level fluctuations on short (annual) and long (5-year) timescales. Therefore, changes in water elevation over 1-year and 5-year periods were used as proxies to represent potential changes to marsh and woody riparian vegetation.

To determine the changes in water elevation under each alternative, CRSS was applied within the DMDU framework to show maximum variability within 1 year and over 5 years in the robustness heat map figures. A 5-year period was selected to represent longer-term variability in water level fluctuations. The modeled variability from CRSS and the DMDU framework were then compared to historic conditions to determine whether variability would remain the same, increase, or decrease for each alternative. For the purposes of this analysis, historic conditions extend from water year (WY) 2008–2025 (the 2007 Interim Guidelines period). Refer to **Section 3.2**, Analysis Methods, for additional information on DMDU and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU robustness heatmaps.

The DMDU calculations are based on the alternatives meeting a preferred minimum performance, defined by a threshold applied to model output values and a frequency over time. If a modeled future meets both the threshold and frequency, it is considered a successful future. For Lake Powell vegetation, the thresholds correspond to the median observed variability in water elevation over 1 year

(for marsh vegetation) and 5 years (for woody riparian vegetation). The CCS Comparative Baseline data displayed on each figure represent the modeled outcome if current management strategies are continued into the future. This information is included for comparative purposes between the alternatives and the modeled future of the analysis area.

Since vegetation can tolerate a range of environmental conditions, failing to meet the threshold criteria once over the full modeling period is not necessarily detrimental to the habitat's establishment or growth over the long term. Therefore, the analysis focuses on the number of times that the model meets the criteria over a 10-year window for marsh vegetation and a rolling 10-year window for woody riparian vegetation.

The GCMRC conducted hydrologic niche modeling for several species on the fixed-site sandbars for each alternative and used these models to estimate the acres of habitat suitability for each species (Butterfield and Palmquist 2026). The data used for this modeling were collected from 2014 to 2019 (Palmquist et al. 2018a) and can be accessed in the associated data release (Palmquist et al. 2022). In addition to habitat suitability, changes to native species richness, proportion native cover, and total native vegetation cover were estimated by combining the modeled habitat suitability. The hydrologic niche modeling includes HFEs. For a detailed analysis of frequency and duration of HFEs under each alternative, see **TA 5**, Geomorphology and Sediment.

Figures presented for this reach are conditional box plots. Refer to **Section 3.2**, Analysis Methods, for additional information on DMDU and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU conditional box plots. The hydrologic niche modeling results used to create these figures can be accessed in the associated data release (Butterfield and Palmquist 2026). The dashed lines included in **Figure TA 9-9** through **Figure TA 9-13**, in **TA 9**, are reference lines to the 50th percentile of modeled 'historical' period, which were modelled using 2000-2025 hydrology under CCS Comparative Baseline using a dry-initial condition (see **Section 3.2.6** for an explanation of initial conditions).

As with Lake Powell, changes in water elevation from historical conditions were used as a proxy to determine potential impacts on marsh and woody riparian vegetation under each alternative for Lake Mead. The same methods for Lake Mead were used as described for Lake Powell.

As with Lake Powell and Lake Mead, the change in water elevation was used as a proxy to determine potential impacts on marsh and woody riparian vegetation under each alternative for the Hoover Dam to SIB reach. However, for this reach, water releases were used to represent changes from historical conditions rather than water elevation. Releases from Hoover Dam, Davis Dam, and Parker Dam were modeled, as releases from these dams determine the amount of water available downstream. Davis Dam and Parker Dam were found to have similar trends as Hoover Dam; therefore, only Hoover Dam results are discussed in detail. The impacts as described in the Hoover Dam to SIB section apply to the entire reach.

Impact Analysis Area

The Lake Powell reach includes Lake Powell up to full pool (water surface elevation 3,700 feet). The Glen Canyon Dam to Lake Mead reach extends from Glen Canyon Dam (RM -15.6) to RM 240. The Glen Canyon Dam to Lake Mead reach begins at Glen Canyon Dam, includes the Colorado River

through Grand Canyon, and ends where Lake Mead at full pool occurs at RM 240. The analysis area for this reach extends to the 45,000-cfs modeled stage elevation, corresponding to the maximum controlled flood releases under the current HFE protocol; the analysis area is considered the active floodplain of the Colorado River in this reach under LTEMP (Reclamation 2016)**.** The section from Glen Canyon Dam to Lake Mead is divided into the following three sub-reaches to account for vegetation community changes (Palmquist et al. 2018b): Marble Canyon (RM -15.6 to RM 60), Eastern Grand Canyon (RM 60 to RM 161), and Western Grand Canyon (RM 161 to RM 240).

The Lake Mead reach extends from RM 240 in the Grand Canyon to Hoover Dam. The analysis area for this reach includes the full pool of Lake Mead (water surface elevation 1,229 feet). The Hoover Dam to SIB reach is aligned with the LCR MSCP planning area. As described in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, there are seven reaches within the LCR MSCP planning area. For vegetation analysis, the analysis area includes LCR MSCP reaches 2 through 7 (Reclamation 2004). Reach 1 in the LCR MSCP planning area includes Lake Mead up to the full pool, which is addressed separately as Lake Mead. The analysis area includes the full pool of Lake Mohave and Lake Havasu and the Colorado River's historical floodplain.

Assumptions

The assumptions used for the analysis of impacts are provided in **Section TA 9.2.1**, Methodology.

Impact Indicators

The following impact indicators were used:

- A change in the median and interquartile ranges from modeled historical conditions (Glen Canyon Dam to Lake Mead reach)
- Changes in water fluctuations within a single year compared with historical conditions (Lake Powell, Lake Mead, and Hoover Dam to SIB reaches)
- Changes in water fluctuations in the preceding 5 years compared with historical conditions (Lake Powell, Lake Mead, and Hoover Dam to SIB reaches)

Issue 1: How would changes in the management of the Colorado River impact vegetation, including special status species

Lake Powell. For all alternatives except for the Enhanced Coordination Alternative and the Maximum Operation Flexibility Alternative, increased variability in the first decade (2027–2039; **Figure TA 9-7** in **TA 9**) compared to modeled historic conditions, indicated by a lower percentage of futures meeting the level of performance, would result in changes in marsh vegetation. Whether an area experiences an increase or a decrease in marsh habitat in response to changed conditions is mostly dependent on local topography, but generally an increase in variability is expected to result in a decrease in marsh vegetation due to more frequent dewatering and inundation. In the first decade, the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative are the most robust, meeting the minimum level of performance in 81 percent and 80 percent of futures, respectively. CCS Comparative Baseline and No Action Alternative meet it in 49 percent and 36 percent of futures, respectively.

In the first decade, cover of prickly Russian thistle may increase due to the increased area of upland habitat created during water elevation fluctuations. Cover of prickly Russian thistle would be expected

to decrease in the later decades if variability also decreases, reducing areas vulnerable to invasive species establishment on an annual basis. Native vegetation can re-establish over time, particularly in areas exposed for more than 3 years (Arens 2023).

In the later decades (2040–2049 and 2050–2060; **Figure TA 9-7** in **TA 9**), the Enhanced Coordination Alternative is the most robust, meeting the minimum level of performance in 92 percent and 90 percent of futures, respectively. CCS Comparative Baseline and No Action Alternative meet it in 54 percent and 48 percent, and 51 percent and 53 percent of futures, respectively. As variability becomes closer to historic conditions for Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative (as indicated by a higher percentage of futures meeting the level of performance), marsh vegetation may re-establish to a similar historical extent under those alternatives.

For the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative under the Critically Dry Flow Category Lake Powell has a modeled WY minimum median elevation of approximately 3,520 feet and 3,512 feet, respectively (see **Table TA 3-4** in **Section TA 3.2**, Environmental Consequences, in **TA 3**, Hydrologic Resources); these median elevations are 38 and 46 feet below, respectively, the minimum 2024 water elevation of 3,558 feet (see **Figure TA 3-1** in **Section TA 3.1**, Affected Environment). Under the Average Flow Category, Lake Powell has a WY modeled minimum median elevation of approximately 3,613 and 3,605 feet for the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative, respectively (see **Table TA 3-4** in **Section TA 3.2**); these median elevations are approximately 55 and 47 feet higher than the minimum 2024 water elevation. This indicates higher modeled elevations under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative under all but the critically dry modeled conditions. If water elevations gradually rise with similar levels of variability to historical conditions (**Figure TA 9-7**), marsh vegetation is expected to continue to reestablish along the new water line over time. If water elevations rise, some of the side canyons that were exposed as Lake Powell receded may reflood, which would inundate the native plant communities that had reemerged.

If water elevations stay the same or gradually fall with similar variability to historical conditions (**Figure TA 9-7**), marsh vegetation may reestablish to a similar extent along the new water line over time. Under these alternatives, plant communities in the side canyons would remain exposed.

Whether water elevations rise, fall, or remain the same, if variability resembles historical conditions under the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative in the later decades, marsh vegetation **(Figure TA 9-7)** and woody riparian vegetation **(Figure TA 9-8)** is expected to continue to reestablish along the new water line over time. For alternatives that have more variability than historical conditions (**Figure TA 9-7, Figure TA 9-8**), marsh and woody riparian vegetation may reestablish to a smaller extent along the new water line over time. Where variability eliminates or prevents the establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type. Whether an area experiences an increase or a decrease in marsh or woody riparian habitat in response to changed conditions is largely dependent on local topography, but generally an increase in variability is expected to result in a decrease in woody riparian vegetation.

The trends and type of impacts on woody riparian vegetation are the same as those described for marsh vegetation for Lake Powell (**Figures TA 9-7** and **TA 9-8**).

Glen Canyon Dam to Lake Mead Suitable Habitat Area – Marsh. Figure TA 9-9 compares the amount of modeled marsh habitat for each alternative by Grand Canyon sub-reach. Marsh vegetation includes bulrushes (*Schoenoplectus* spp.), rushes (*Juncus* spp.), field horsetail (*Equisetum arvense*), and common reed (*Phragmites australis*).

In Marble Canyon and Eastern Grand Canyon, under the Average Flow Category, Moderately Wet Flow Category, and Dry Flow Category, the medians are near modeled historic conditions (dashed line) and the interquartile ranges are relatively restricted and overlap the modeled historic conditions (**Figure TA 9-9**) for all alternatives, indicating that the amount of habitat suitable for marsh species would likely be similar to historic conditions under these categories. Under the Critically Dry Flow Category, the Maximum Operational Flexibility Alternative, Supply Driven Alternative, and Representative Preferred Alternative medians and interquartile ranges are completely above modeled historic conditions (dashed line), indicating that suitable habitat for marsh species may increase under the Critically Dry Flow Category for those alternatives. Under the Wet Flow Category, the medians and interquartile ranges are mostly below modeled historic conditions (dashed line) for all alternatives, suggesting there would likely be less suitable marsh habitat under all alternatives.

Further downstream in Western Grand Canyon, wider interquartile ranges suggest greater uncertainty in the amount of modeled suitable marsh habitat. The general trends follow that of Marble Canyon and Eastern Grand Canyon, but with more differentiation in the Moderately Wet and Dry Flow Categories; there would likely be similar levels of marsh habitat under the Average Flow Category, less marsh habitat under the Wet and Moderate Wet Flow Categories, and more marsh habitat under the Dry and Critically Dry Flow Categories. Under the Average, Dry, and Critically Dry Flow Categories, the CCS Comparative Baseline and Enhanced Coordination Alternative have wider interquartile ranges than the other alternatives, suggesting greater uncertainty.

The decrease in suitable habitat for marsh species under the Wet Flow Category for all sub-reaches and all alternatives may occur because higher water levels may reduce the overall available terrestrial habitat in the river's active channel (Sankey et al. 2015). The similarity or increase in suitable habitat for marsh species under the Critically Dry Flow Category (4.46–10.0 maf) and the Dry Flow Category for all sub-reaches and all alternatives may be because decreasing water levels increase the amount of exposed shoreline habitat.

Glen Canyon Dam to Lake Mead Suitable Habitat Area – Woody Riparian. Figure TA 9-10 compares the amount of modeled woody riparian habitat for each alternative by Grand Canyon sub-reach. Woody riparian vegetation includes seepwillow (*Baccharis* spp.), arrowweed (*Pluchea sericea*), honey mesquite (*Prosopis glandulosa*), and coyote willow (*Salix exigua*).

Across all three sub-reaches, similar interquartile ranges would suggest woody riparian suitable habitat would respond in a similar way across all alternatives under each Flow Category. However, the wide interquartile ranges suggest a high amount of uncertainty about how vegetation would respond under each of the modeled conditions and alternatives in all three sub-reaches.

Similar to marsh habitat, under the Average, Moderately Wet Flow, Wet Flow, and Dry Flow Categories, there is less suitable habitat for woody riparian species, as indicated by the median remaining below the modeled historic conditions under all sub-reaches and across all alternatives except for the No Action Alternative and Enhanced Coordination Alternative in the Dry Flow

Category. For some alternatives, the interquartile range expands above the modeled historic conditions (dashed line), indicating uncertainty about how vegetation would respond. Under the Critically Dry Flow Category, the medians are typically above the modeled historic conditions (dashed line), indicating a likely increase in suitable habitat for woody riparian vegetation under all alternatives except for the Maximum Flexibility Alternative. However, the large interquartile ranges extend far above as well as below the modeled historic conditions (dashed line) under all reaches and for all alternatives except for the No Action Alternative, indicating the variability is too high to predict whether there would be more or less suitable habitat for woody riparian species under these alternatives. The No Action Alternative remains above the modeled historical conditions for all three sub-reaches. This may be because under the No Action Alternative, there would be less water available, compared with the other alternatives, and thus more exposed shoreline that can support woody riparian species.

Similar to marsh habitat, the decrease in suitable habitat for woody riparian species under the Moderately Wet Flow Category and Wet Flow Category for all sub-reaches and all alternatives may be because higher water levels reduce the overall available terrestrial habitat (Sankey et al. 2015). Whereas suitable habitat for woody riparian species may increase under the Critically Dry Flow Category; this expansion would occur near river level on areas recently exposed by lower water levels. Suitable habitat for both woody riparian and marsh species may overlap in these recently exposed areas, where these habitat types would compete near the river. In areas near the top of the active floodplain, decreasing water levels may provide an opportunity for an increase in upland habitat due to disconnection from the river.

Glen Canyon Dam to Lake Mead Suitable Habitat Area – Arrowweed. Figure TA 9-11 compares arrowweed suitable habitat under each alternative by Grand Canyon sub-reach. Across all three reaches, all alternatives show similar trends: the generally similar and overlapping interquartile ranges suggest arrowweed would respond in a similar way across all alternatives. Arrowweed would respond similarly to marsh and woody riparian habitat: there would be less arroweed suitable habitat under wetter conditions and more arrowweed suitable habitat under drier conditions.

Glen Canyon Dam to Lake Mead – Native Species Richness. Figure TA 9-12 compares the predicted count number of native species (native species richness) under each alternative by Grand Canyon sub-reach. Native species richness includes all habitat types and does not distinguish between marsh, woody riparian, and upland. Across all three sub-reaches, all alternatives show similar trends: The wide and generally similar interquartile ranges suggest native species richness would respond in a similar way across all alternatives.

Under all alternatives, sub-reaches, and flow categories, the median is below the modeled historic conditions (dashed line). For some modeled conditions, the interquartile range is above the modeled historic conditions, indicating uncertainty in how vegetation would respond. Since most of the interquartile range is still below the modeled historic conditions, native species richness may decrease under all modeled conditions. However, given the large interquartile ranges, it is difficult to predict how each alternative may respond. Similar to marsh habitat, the Western Grand Canyon reach has larger interquartile ranges than Marble Canyon and Eastern Grand Canyon, indicating greater uncertainty further downstream.

Species richness at the fixed-site sandbars declined from 2014 to 2019. This trend was driven by low species richness in 2019 (Palmquist et al. 2023). The low species richness in 2019 was likely caused by the HFE that occurred in fall 2018 and the lack of monsoon precipitation in summer 2019. Native species richness may decrease under wet hydrologic conditions because HFEs would be a more frequent occurrence and may decrease under the Critically Dry Flow Category due to a lack of precipitation. Disturbance created by HFEs can also positively impact native species richness, as some species require periodic disturbance. Native species richness may also decrease under the Critically Dry Flow Category due to a lack of HFEs. Under all conditions, a combination of these hydrologic and climatic factors may be driving the variable interquartile ranges.

Glen Canyon Dam to Lake Mead – Proportion Native Species Cover. Figure TA 9-13 compares the proportion of native species cover under each alternative by Grand Canyon sub-reach. The proportion native species cover includes all habitat types and does not distinguish between marsh, woody riparian, and upland vegetation. Across all three sub-reaches, all alternatives show similar trends: The generally wide and similar interquartile ranges in each sub-reach suggest the proportion of native cover would respond in a similar way across all alternatives.

Similar to native species richness, the proportion of native species cover has large interquartile ranges across all modeled conditions and all alternatives. This indicates a large amount of uncertainty in how vegetation would respond under various conditions. Under all reaches, under the Wet, Moderately Wet, Average, and Dry Flow Categories modeled conditions, the median is below the modeled historic conditions (dashed line) for all alternatives except for the No Action Alternative and Basic Coordination Alternative under Average and Dry Flow Categories. Since most of the interquartile ranges are below the modeled historic conditions, the proportion of native cover may decrease under Wet, Moderately Wet, Average, and Dry Flow Category conditions under all alternatives and all sub-reaches. However, given the large interquartile ranges, it is difficult to predict how vegetation may respond under each of the modeled conditions, alternatives, and sub-reaches.

For all sub-reaches, under the Critically Dry Flow Category modeled conditions, the median and interquartile range is above the modeled historic conditions (dashed line) under all alternatives except for the Maximum Operational Flexibility Alternative. This suggests that under the Critically Dry Flow Category modeled conditions, the proportion native cover may stay similar to historic conditions or increase under most alternatives. However, given the large interquartile ranges, it is difficult to predict how vegetation may respond under each alternative.

Encroachment of riparian vegetation into the exposed active channel and into the bare sand of sandbars has been found to be driven by seepwillows, which are a native species (Durning et al. 2021). The proportion of native species cover may decrease under all conditions except for the Critically Dry Flow Category due to the lack of bare sand available for native species, particularly seepwillows, to colonize. The proportion of native cover may increase under the Critically Dry Flow Category because of receding water levels and subsequent increase in available sand.

Glen Canyon Dam to Lake Mead – Annual Total Vegetation Cover. Figure TA 9-14 compares the annual total vegetation cover under each alternative by Grand Canyon sub-reach. Annual total vegetation cover includes all habitat types and does not distinguish between marsh, woody riparian, and upland. Across all three reaches, all alternatives show similar trends: The generally similar and

overlapping interquartile ranges suggest annual total vegetation cover would respond in a similar way across all alternatives.

Under the Average Flow Category, across all three sub-reaches, the median for each alternative overlaps or nearly overlaps the modeled historic conditions (dashed line), and the interquartile ranges are relatively small. This indicates that annual total vegetation may be similar to historic conditions under the Average Flow Category.

Across all three sub-reaches, under the Wet Flow Category and Moderately Wet Flow Category, the median and interquartile ranges are at or below the modeled historic conditions (dashed line) for all alternatives except for the interquartile range of the No Action Alternative in the Moderately Wet Flow Category, although the median remains below historic conditions. This suggests that there would be less annual total vegetation cover under the Wet and Moderately Wet Flow Categories under all sub-reaches and all alternatives. Under the Dry Flow Category, the medians are above historic conditions (dashed line) for all alternatives except the CCS Comparative Baseline and Enhanced Coordination Alternative. Under the Critically Dry Flow Category the median and interquartile ranges are above the modeled historic conditions (dashed line) for all sub-reaches and all alternatives except for the CCS Comparative Baseline. This indicates that there may be more annual total vegetation cover under Critically Dry Flow Category.

Similar to the discussions above under *Suitable Habitat Area*, the decrease in annual total vegetation cover under the wet and moderately wet modeled conditions for all sub-reaches and all alternatives may be because higher water levels reduce the overall available terrestrial habitat (Sankey et al. 2015). Conversely, annual total vegetation cover may increase under the Dry and Critically Dry Flow Categories, likely on areas recently exposed by lower water levels. Fewer to no HFEs under the Dry and Critically Dry Flow Categories could also lead to higher vegetation encroachment.

High Flow Experiments

HFEs influence vegetation dynamics in this reach depending on geomorphic setting, duration, and flow volume. HFEs are dependent on sufficient storage and sediment conditions at Lake Powell. Alternatives that prioritize retaining higher levels in Lake Powell are more likely to result in HFEs, which could influence modeled vegetation responses in this reach. The role of HFEs on shaping vegetation in this reach are described in greater detail in the 2024 LTEMP SEIS (Reclamation 2024c).

Lake Mead. In the first decade, all alternatives are equally non-robust, meeting the minimum level of performance in 0 percent of futures. For all alternatives, the increased variability from historical conditions in the first decade (2027–2039; **Figure TA 9-15**) of the analysis may result in decreased cover of marsh vegetation. In later decades (2040–2049 and 2050–2060; **Figure TA 9-15**) when variability becomes closer to historical conditions for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, marsh vegetation may reestablish to a more similar extent compared to the other alternatives. Both of these alternatives are more robust than the CCS Comparative Baseline and No Action Alternative, which meet the minimum level of performance in 16 percent and 14 percent, and 10 percent and 10 percent of futures, respectively. Similar to Lake Powell, when conditions are more variable, cover of nonnative species, such as prickly Russian thistle, may increase; if variability decreases, native cover may reestablish.

As shown in **Figure TA 3-11** (see **TA 3.2**), the interquartile ranges for all alternatives for the Average Flow Category are above the 2024 WY minimum of 1,061 feet except for the No Action Alternative. The interquartile ranges under the Dry Flow Category are closer to the 2024 WY minimum compared to the Average Flow Category, and the interquartile ranges overlap with the 2024 WY minimum for all alternatives under the Critically Dry Flow Category. This suggests that Lake Mead is likely to lower under drier conditions. Conversely, under the Moderately Wet and Wet Flow Categories, the interquartile ranges shift to be higher than the 2024 WY minimum of 1,061 feet (**Figure TA 3-11**, see **TA 3.2**), suggesting that Lake Mead would rise under wetter conditions.

Similar to Lake Powell, whether water elevations rise, fall, or remain the same, if there are similar levels of variability to historical conditions under the Basic Coordination Alternative, Maximum Operational Flexibility Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) in the later decades (**Figure TA 9-15**), marsh vegetation is expected to continue to reestablish along the new water line over time. For alternatives with greater variability than historical conditions (**Figure TA 9-15**), marsh vegetation may reestablish to a smaller extent along the new water line over time. Where variability eliminates or prevents the establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type.

Similar to Lake Powell, the first decade of modeling for woody riparian vegetation is influenced by historical data (**Figure TA 9-16**). All alternatives meet the minimum level of performance in 12 percent or less of futures. The later decades (2040–2049 and 2050–2060; **Figure TA 9-16**) begin to trend towards more similar variability compared to historic conditions, but variability still remains high. The Basic Coordination Alternative and the Maximum Operational Flexibility Alternative are more similar to historic conditions, meeting the minimum level of performance in 26 percent and 50 percent and 22 percent and 52 percent of futures, respectively. Both of these alternatives are more robust than the CCS Comparative Baseline and No Action Alternative, which meet the minimum level of performance in 20 percent and 22 percent, and 20 percent and 24 percent of futures, respectively.

In later decades (2040–2049 and 2050–2060; **Figure TA 9-16**), when variability becomes more similar to historical conditions for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, woody riparian vegetation may reestablish to a more similar extent as existing conditions compared to other alternatives. Where variability eliminates or prevents the establishment of woody riparian habitat, upland habitat may become the dominant habitat type.

Figures TA 9-15 and **TA 9-16** suggest that annual variability in Lake Mead water elevations may be higher, especially in the early decade of the modeling period; however, the variability on a 5-year basis may overall be closer to historical conditions, generally benefiting woody riparian vegetation.

Hoover Dam to the SIB. Similar to Lake Powell and Lake Mead, the first decade of modeling for marsh vegetation is influenced by historical data (**Figure TA 9-17**). In the first decade, the Basic Coordination Alternative is the most robust, meeting the minimum level of performance in 60 percent of futures. CCS Comparative Baseline Alternative and No Action Alternative meet it in 55 percent and 6 percent of futures, respectively. For all alternatives, the increased variability from historic conditions in the first decade (2027–2039; **Figure TA 9-17**) may result in decreased marsh vegetation cover.

In later decades (2040–2049 and 2050–2060; **Figure TA 9-17**), all alternatives trend towards more similar variability compared to historic conditions. All alternatives meet the minimum level of

performance in 78 percent or more of futures. The CCS Comparative Baseline and No Action Alternative meet it in 63 percent and 61 percent, and 63 percent and 55 percent of futures, respectively. As variability becomes closer to historical conditions, marsh vegetation may reestablish to a similar extent. Where variability eliminates or prevents establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type.

During the 2007 Interim Guidelines period, the annual volume of the Colorado River below Hoover Dam averaged 9.185 maf (see **Section TA 3.1**). For all alternatives under the Average and Dry Flow Categories the interquartile ranges of the modeled annual volume are below 9.185 maf (**Table TA 3-21** and **Figure TA 3-27** in **Section TA 3.2**). This suggests that the annual flow volume below Hoover Dam may decrease under all alternatives under the Average and Dry Flow Categories. The 2007 Interim Guidelines reduced the average annual releases from Hoover Dam by approximately 1.014 maf from prior operating guidelines (**Section TA 3.1**). As described in **Section TA 9.1**, the recent change analysis indicates marsh vegetation generally decreased from 2000 to 2024 (RiverRestoration.Org 2025). If water releases decrease with higher levels of variability, compared with historical conditions (**Figure TA 9-17**), marsh vegetation is expected to continue to decrease over time under Average and Dry Flow Categories. If water releases decrease with similar levels of variability as historical conditions (**Figure TA 9-17**), marsh vegetation is expected to decline at a rate similar to existing conditions under Dry and Critically Dry Flow Categories.

Similar to Lake Powell and Lake Mead, the first decade of modeling for woody riparian vegetation is influenced by historical data (**Figure TA 9-18**). In the first decade, all alternatives are equally non-robust, meeting the minimum level of performance in 0 percent of futures. Increased variability from historic conditions in the first decade (2027–2039; **Figure TA 9-18**) may result in decreased woody riparian vegetation cover due to inconsistent water availability.

In later decades (2040–2049 and 2050–2060; **Figure TA 9-18**), alternatives trend towards variability more similar to historic conditions. The Basic Coordination Alternative is the most robust, meeting the minimum level of performance in 45 percent and 40 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 30 percent and 27 percent, and 29 percent and 26 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 17 percent and 12 percent, and 21 percent and 19 percent of futures, respectively. This increased variability may result in decreased riparian vegetation cover under all alternatives, but to a lesser extent under the Basic Coordination Alternative and No Action Alternative. Where variability eliminates or prevents woody riparian habitat establishment, upland habitat may become the dominant habitat type.

Summary Comparison of Alternatives

Table TA 9-4 in **Section TA 9.2** provides a comparison of alternatives that are most and least similar to historical conditions for each reach.

For Lake Powell marsh and woody riparian vegetation, the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative would result in vegetation most similar to historical conditions. The Maximum Operational Flexibility Alternative would also result in vegetation most similar to historical conditions for Lake Mead's marsh and woody riparian vegetation. However, for the Hoover Dam to the SIB reach, the Maximum Operational Flexibility Alternative and the Enhanced

Coordination Alternative would result in vegetation least similar to historical conditions, which would result in larger changes in vegetation, compared with historical conditions, for that reach. Similarly, the Basic Coordination Alternative would result in conditions least similar to historical conditions for Lake Powell, but would be closest to historical conditions for Lake Mead and Hoover Dam to the SIB. This suggests that no single alternative would result in vegetation similar to historical conditions across all reaches.

For all reaches, multiple alternatives provide variability more similar to historical conditions than the CCS Comparative Baseline, except for the Hoover Dam to SIB reach, where only the Basic Coordination Alternative would result in variability more similar to historical conditions. This suggests that a change in management from current strategies would benefit a large portion of the analysis area; however, it would not benefit the Hoover Dam to SIB reach unless the Basic Coordination Alternative is selected.

For the Glen Canyon Dam to Lake Mead reach, the alternative that would result in vegetation most similar to historical conditions depends strongly on the flow categories. Across all alternatives, all sub-reaches, and all evaluated criteria (the suitable habitat area, native species richness, proportion of native species cover, and annual total vegetation cover), the interquartile ranges often overlap. When the interquartile ranges overlap, it is difficult to determine whether one alternative is truly different from another. Therefore, no single alternative emerged as the best or worst for retaining vegetation similar to historical conditions.

Under all alternatives for Lake Powell, Lake Mead, and Hoover Dam to the SIB, the first decade would experience more variability, which would result in a reduction in marsh and woody riparian habitat compared with historical conditions. All alternatives would see conditions return closer to historical conditions in the second and third decades, which may result in vegetation reestablishing to a similar extent. Where variability eliminates or prevents the establishment of marsh, woody riparian, or upland habitat, there may be a shift to one of the other habitat types.

3.10 Terrestrial Wildlife Including Special Status Species

3.10.1 Affected Environment

This section provides an overview of the general terrestrial wildlife typically found within marsh, woody riparian, and upland habitats in the analysis area, as described in **Section 3.9**, Vegetation Including Special Status Species, including invertebrates, amphibians, reptiles, birds, and mammals. This section also includes special status species, which are defined here as those listed as BLM sensitive species in the overlapping Arizona, California, Utah, and Nevada BLM field offices; species covered under the LCR MSCP; and species listed as threatened, endangered, or proposed for listing by the FWS (BLM 2017, 2018, 2019, 2023; LCR MSCP 2022; FWS 2025). **Attachment 1** in **TA 10**, Terrestrial Wildlife Including Special Status Species, provides a table of the species considered in this document, including their listing status, the river reaches they typically inhabit, and the habitat types most important to their life histories. **Attachment 1** in **TA 10** was developed with input from cooperating agencies and local experts. A full description of the wildlife and special status species that use each of the habitat types is provided in **Section TA 10.1**, Affected Environment, in **TA 10**.

In addition to analyzing the impacts on wildlife in the analysis area as defined in **Section 3.9**, Vegetation Including Special Status Species, impacts are also evaluated for the LCR MSCP conservation areas. These areas were established to provide habitat for species listed under the ESA or that may become listed under the ESA and that use habitat along the Colorado River from Lake Mead down to the SIB (LCR MSCP 2025). The Colorado River in this area has been highly modified by several dams and water diversions, which have affected the growth and establishment of marsh and woody riparian habitat (see **Section 3.9.1**, Affected Environment). The LCR MSCP Habitat Conservation Plan (HCP) and subsequent ESA consultations identified the impacts on marsh, woody riparian, upland, and backwater habitats predicted from existing and anticipated future river operations, and the program established the conservation areas and off-river land acquisitions to mitigate for these losses and provide reliable suitable habitat for wildlife (LCR MSCP 2025). There are 18 conservation areas aimed at conserving 27 species, with a goal of creating 5,940 acres of cottonwood/willow, 1,320 acres of honey mesquite, 568 acres of marsh, and 484 acres of backwater habitats. In addition to the conservation areas, several wildlife refuges and lands managed for wildlife and recreation are present below Hoover Dam. These include Havasu National Wildlife Refuge, Bill Williams River National Wildlife Refuge, Cibola National Wildlife Refuge, Imperial National Wildlife Refuge, Gooseflats Wildlife Area, Lake Mead National Recreation Area, and Mittry Lake Wildlife Management Area.

Section 3.9, Vegetation Including Special Status Species, describes the marsh, woody riparian, and upland habitat types, which are used in this section to determine the affected environment and environmental impacts on wildlife, including special status species. For additional information on the wildlife species considered in this analysis by habitat type, please reference **Section TA 10.1**, Affected Environment, in **TA 10**, Terrestrial Wildlife Including Special Status Species.

3.10.2 Environmental Consequences

Methodology

This Terrestrial Wildlife section relies on the outcomes of the vegetation analysis, the methodology for which is outlined in the Methodology subsection of **Section 3.9.2**, Environmental Consequences.

Impact Analysis Area

The analysis area is the same as described in the Impact Analysis Area subsection of **Section 3.9.2**, Environmental Consequences.

Assumptions

- Upland wildlife species, including special status species, that do not rely directly on the Colorado River or on woody riparian and marsh vegetation influenced by elevation or flows are not included in the impact analysis because changes in operations would not impact these species.
- The evaluation of impacts on wildlife, including special status species, are driven by impacts on vegetation modeling in **Section 3.9** (DMDU-based vegetation analysis).

Impact Indicators

These indicators align with the DMDU figures in **Section 3.9**.

- For terrestrial wildlife species using marsh habitat, changes in water fluctuations within a single year compared with historical conditions
- For terrestrial wildlife species using woody riparian habitat, changes in water fluctuations in the preceding 5 years compared with historical conditions
- For terrestrial wildlife species using upland habitat, changes in water fluctuations over either the preceding single year or preceding 5 years compared with historical conditions

Issue 1: How would changes in the management of the Colorado River impact terrestrial wildlife species habitat availability, including special status species?

Lake Powell

As discussed in **Section 3.11.2**, Environmental Consequences, Lake Powell's surface water elevations fluctuate on a short-term (annual) and long-term (5-year) scale, which causes changes in water availability and which results in the establishment, reestablishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife, including special status species (hereafter collectively referred to as wildlife), that currently use the Lake Powell analysis area have adapted to these changing conditions.

Under all alternatives, modeling indicates a greater range of variability in Lake Powell's surface elevations compared with historic conditions for both marsh and woody riparian habitat in the first decade (2027–2039) (**Figure TA 9-7** and **Figure TA 9-8** in **TA 9**, Vegetation Including Special Status Species). As described in **Section TA 9.2**, Environmental Consequences, in **TA 9**, Vegetation Including Special Status Species, this greater variability would result in changes in the vegetation extent compared with existing conditions and could decrease vegetation cover. While Lake Powell would continue to support at least some upland, marsh, and woody riparian habitat, the location of conditions suitable to support each of these habitat types is likely to change. Areas that currently support marsh, woody riparian, or upland habitat could transition to one of the other habitat types. Side-canyons that have been exposed due to lower water levels have had an increase in native vegetation, which likely provides suitable wildlife habitat for a range of wildlife species. An increase in water levels could result in the loss of suitable habitat in these areas.

With increased variability, wildlife would have to adapt to changing habitat availability on a larger scale than under historical conditions. For those species capable of moving long distances, such as large mammals, bats, birds, and some amphibians, reptiles, and invertebrates, this change in habitat availability would likely have fewer long-term impacts, provided that suitable habitat is available within their dispersal or migratory range. Habitat transitions could also result in the range expansion or contraction of some species, including into new reaches, as they adapt to changing habitat availability. For less mobile species, such as some small mammals, amphibians, reptiles, and invertebrates, the transition from one habitat type to another may impact foraging, breeding, or sheltering behaviors, which can impact survival and reproduction. Decreased survival and reproduction on a large scale can result in a decreased population size. Smaller local populations are more vulnerable to changes in the environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

During the second decade (2040–2049) and third decade (2050–2060), modeling indicates a range of variability more similar to historical conditions under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative compared with the other alternatives as well as compared with the first decade (2027–2039; **Figure TA 9-7** and **Figure TA 9-8** in **TA 9**, Vegetation Including Special Status Species). This would result in habitat variability similar to what is currently on the landscape; wildlife would need to adapt to changing habitat conditions at the same scale as historical conditions. For all other alternatives, variability would remain high in the second and third decades (as indicated by lower percentages of futures meeting the level of performance), and wildlife would continue to need to adapt to changing habitat availability on a larger scale compared with historical conditions.

In addition to the annual and 5-year changes in water elevation, modeling indicates Lake Powell would gradually rise in elevation over time under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative in all but the Critically Dry Flow Category (**Table TA 3-4** and **Figure TA 3-1** in **TA 3**, Hydrologic Resources). This would result in a shift of marsh and woody riparian vegetation along the new shoreline over time. The rise in water elevation would result in a marginal loss of upland habitat but is not likely to impact wildlife that use marsh or woody riparian habitat, as the shift would be gradual enough for vegetation to continue to reestablish along the new shoreline. Under all other alternatives, modeling indicates water levels would remain the same or decrease in elevation. Similarly, vegetation would reestablish along the lower shoreline as the water elevations change over time. As water elevations lower, the distance to water for upland species would increase. However, given the ability for vegetation to adapt to changing water levels, this change in water elevation, either to a higher elevation under the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative or to a similar or lower elevation under all other alternatives, would not likely impact foraging, breeding, or sheltering behaviors for wildlife. Lower water levels can raise the risk of harmful algal blooms. This risk applies to all alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives and under all conditions except for the Critically Dry Flow Category. This could impact wildlife directly through increased toxicity exposure or indirectly through reductions in habitat quality and quantity.

While monarch butterflies (*Danaus plexippus plexippus*) primarily use woody riparian habitat for migration, they also use marsh and upland habitat regularly. Given the shifting availability of marsh, woody riparian, and upland habitat, and the ability to use features from all three habitat types, monarch butterflies are likely to be able to find suitable habitat under all alternatives in the Lake Powell analysis area. Species-specific impacts will be addressed in future ESA Section 7 Biological Opinions (BOs).

Glen Canyon Dam to Lake Mead

Similar to Lake Powell, the Glen Canyon Dam to Lake Mead reach experiences fluctuating water levels that cause changes in water availability, which results in the establishment, reestablishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Glen Canyon Dam to Lake Mead analysis area have had to adapt to these changing conditions in the past.

As shown in **Figure TA 9-9** and **Figure TA 9-10** in **TA 9**, Vegetation Including Special Status Species, the amount of suitable habitat for marsh and woody riparian habitat across all three sub-reaches of the Glen Canyon Dam to Lake Mead reach is modeled to respond similarly under all alternatives, and the wide interquartile ranges in **Figure TA 9-10** in **TA 9**, Vegetation Including Special Status Species,

indicate that future acreages of woody riparian habitat are difficult to predict. For marsh and woody vegetation, for all alternatives and sub-reaches, there is less suitable habitat under the Wet and Moderately Wet Flow Categories and more suitable habitat under the Dry and Critically Dry Flow Categories compared to modeled historical conditions. The Western Grand Canyon sub-reach has wider interquartile ranges, which suggests greater uncertainty in how vegetation will respond under the various alternatives. Woody vegetation has larger interquartile ranges than marsh vegetation, and therefore greater uncertainty. The amount of habitat available for wildlife species, including southwestern willow flycatcher (*Empidonax traillii extimus*) and yellow-billed cuckoo (*Coccyzus americanus*), is affected primarily by modeled conditions rather than by the alternatives. Species-specific impacts will be addressed in future ESA Section 7 BOs.

Similar patterns are apparent for native species richness, proportion of native species cover, and annual total vegetation cover (**Figures TA 9-12**, **TA 9-13**, and **TA 9-14** in **TA 9**, Vegetation Including Special Status Species). Increased species richness, proportion of native species cover, and annual total vegetation cover would be beneficial to wildlife species for foraging and breeding habitat. However, increases in each of these factors are driven by the modeled conditions rather than by the alternatives, with additional habitat available under the Critically Dry Flow Category. This is likely due to encroachment of vegetation into areas exposed by lower water levels.

With potentially decreasing water levels at Lake Powell, the temperature of releases from Glen Canyon Dam could increase, increasing the potential for harmful algal blooms in the Glen Canyon Dam to Lake Mead reach. Harmful algal blooms could impact wildlife directly through increased toxicity exposure or indirectly by reducing habitat quality and quantity (see **TA 6**, Water Quality).

Lake Mead

Similar to Lake Powell, Lake Mead experiences fluctuating water levels on an annual and 5-year time scale that cause changes in water availability, which results in the establishment, reestablishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Lake Mead analysis area have had to adapt to these changing conditions in the past.

As described for Lake Powell, the first decade (2027–2039) exhibits higher variability compared with historical conditions under all alternatives, which would result in changes in habitat availability on a larger scale compared with existing conditions (**Figure TA 9-7** and **Figure TA 9-8** in **TA 9**, Vegetation Including Special Status Species). Marsh and woody riparian vegetation is expected to decrease in response to the increase in variability.

Wildlife species that are capable of moving longer distances would be less likely to be affected by increased variability, provided that suitable habitat is available within their dispersal or migratory range. Even for species that are highly mobile, there may be energetic costs to finding suitable habitat in a fragmented landscape if the distance between suitable habitat locations is outside their typical movement patterns. Increased energetic costs can impact survival and reproduction. Species that are less mobile may experience impacts on foraging, breeding, or sheltering behaviors, which can also impact survival and reproduction. Decreased survival and reproduction through increased energetic costs while searching for suitable habitat or through impacts on foraging, breeding, or sheltering behaviors can result in a decreased population size. Smaller local populations are more vulnerable to

changes in the environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

Unlike Lake Powell, at Lake Mead the second decade (2040–2049) and third decade (2050–2060) exhibit variability similar to historical conditions for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, rather than the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative. However, the impacts on wildlife would be the same as described under Lake Powell for the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative. That is, wildlife would need to adapt to changing habitat conditions at a rate more similar to historical conditions under the Basic Coordination Alternative and Maximum Operational Flexibility Alternative and would need to adapt to changing habitat conditions on a larger scale for the remaining alternatives.

As described in **Section TA 9.2**, Environmental Consequences, in **TA 9**, Vegetation Including Special Status Species, for all alternatives, Lake Mead elevations could rise, fall, or remain the same compared with existing conditions under all alternatives (**Figure TA 3-11** in **TA 3**, Hydrologic Resources). Similar to Lake Powell, whether the water elevations increase, decrease, or stay the same compared with existing conditions, wildlife would likely be able to adapt to these slower changes and follow the vegetation as it reestablishes along the shoreline. Should water elevations decrease under any of the alternatives, the lowering of the water elevation in Lake Mead could increase the potential for harmful algal blooms, which could impact wildlife directly through increased toxicity exposure or indirectly through reduced habitat quality and quantity.

Listed threatened and endangered species with potential to occur in the Lake Mead analysis area consist of southwestern willow flycatcher, yellow-billed cuckoo, Yuma Ridgway's rail (*Rallus obsoletus yumanensis*), and Mojave desert tortoise (*Gopherus agassizii*). Impacts have been previously assessed in the LCR MSCP HCP, 2007 Final EIS, and 2004 SEIS and associated BOs. Additional ESA Section 7 and Section 10 processes are ongoing, and additional impacts will be disclosed in future BOs and HCPs.

Southwestern willow flycatcher and yellow-billed cuckoo rely on woody riparian habitat, which has modeled increased variability and therefore decreased habitat availability in the first decade compared with historical conditions. These species are capable of moving long distances to access suitable habitat, although southwestern willow flycatchers exhibit local site fidelity and most readily colonize sites that are near existing breeding sites. The loss of suitable breeding habitat in a river reach could result in southwestern willow flycatchers being slow to recolonize the area even if suitable habitat redevelops. For both species, if water levels fluctuate or rise to the extent that habitat is unavailable, then impacts on nesting may occur.

Yuma Ridgway's rails rely on marsh habitat, which may also experience increased variability and therefore decreased habitat availability in the first decade compared with historical conditions. Yuma Ridgway's rails are also capable of moving long distances to access suitable habitat, although the readiness with which they colonize new areas far from established breeding sites is unclear. For all three species, as variability returns closer to historical conditions in the second and third decades for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, availability of suitable habitat would likely be similar to historical conditions.

Mojave desert tortoises rely on upland habitat. While upland habitat availability is modeled to change under all alternatives in each of the decades, Mojave desert tortoises would have suitable habitat available upslope and would be capable of moving away from rising water levels. Survivorship would depend on the quantity and quality of available forage in the areas they relocate to. As water levels fluctuate, upland habitat loss would be equal to the areas of change unless water fluctuations stabilize and upland vegetation is able to reestablish. Decreased survival and reproduction on a large scale can result in a decreased population size. Smaller local populations are also more vulnerable to changes in the environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

As described for Lake Powell, monarch butterflies are likely to find suitable habitat under each alternative and are unlikely to be affected.

Hoover Dam to SIB

Similar to Lake Powell and Lake Mead, the Hoover Dam to SIB reach experiences fluctuating water levels on an annual and 5-year timescale that causes changes in water availability, which results in the establishment, reestablishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Hoover Dam to SIB analysis area had to adapt to these changing conditions in the past.

The LCR MSCP HCP and subsequent BOs set habitat creation goals to mitigate for predicted impacts from covered river operations including flow reductions, water delivery and diversion, changes in point of diversion, generation of hydropower, and operation and maintenance activities in the LCR MSCP planning area (Reclamation 2004; FWS 2005, 2018, 2022, 2024). A summary of the habitat creation goals and habitat created toward those goals as of 2025 (LCR MSCP 2025) are included as **Table 3-5**. Habitat creation goals assumed the predicted habitat impacts from reductions in flow and changes in points of diversion up to 2.083 mafy may occur annually until 2055 and would be permanent, even if impacts never actually occur. Habitat would be created to replace it in LCR MSCP conservation areas. This includes a prediction that all existing cottonwood-willow land cover supported by the river and river connected groundwater would be lost due to flow-related covered activities (with the exception of habitat at Topock Marsh and Lake Havasu). Impacts on marsh from flow reductions from 2.083 mafy to 3 mafy were predicted to be short term in duration and the habitat would recover when inundated again (FWS 2024).

These habitat creation goals are the minimum amount of land cover to be created to meet the habitat requirements for the listed and unlisted species covered by the program. Habitat created by the LCR MSCP will be designed in an integrated mosaic and managed for more than one covered species, including habitat elements for each species.

Table 3-5
Summary of Habitat Creation Goals and Habitat Acres Created from Lake Mead to the SIB

Habitat Type	Habitat Creation Goal (Acres)	Habitat Created through 2025 (Acres)
Marsh	568	362
Woody Riparian (cottonwood-willow only)	5,940	4,954
Woody Riparian (honey mesquite only)	1,320	2,046
Woody Riparian (total)	7,260	7,000

Sources: For habitat creation goals, Reclamation 2004; FWS 2005, 2022, 2024. For habitat created through 2025, LCR MSCP 2020, 2025.

Table 3-6 and **Table 3-7** detail the number of acres affected, habitat created, and habitat creation commitments. Although it is unknown exactly how many acres of habitat will be affected over the next 30 years, referencing the number of acres affected over the last 20 years, the amount of habitat present in the reaches (**Table TA 9-1** in **TA 9**), and how those acres were mitigated allows for a greater understanding of future implications. Future impacts and habitat creation commitments will be included in ESA Section 7 BOs and Section 10 HCPs.

Table 3-6
Summary of Federal and Nonfederal Flow-Related Impacts Included in 2004, 2018, 2022, and 2024 HCPs and BOs

Species	Federal and Nonfederal Flow-Related Impacts (Acres)				
ESA Section 7 Consultation	2004 BO and HCP	Additional Impacts in 2018 Biological Assessment, BO, and HCP	Additional Impacts in 2022 Biological Assessment and BO	Additional Impacts in 2024 Biological Assessment and BO	Total
Yuma Ridgway's rail	133	N/A	7	84	224
Southwestern willow flycatcher	1,784	N/A	0	0	1,784
Yellow-billed cuckoo	1,425	N/A	0	0	1,425
Mojave desert tortoise	0	N/A	0	0	0
Northern Mexican gartersnake	N/A	1,081	7	84	1,172

Under all alternatives, all LCR MSCP conservation areas would retain their water entitlements. During shortage conditions, conservation areas with lower priority water rights (4th to 6th level priorities) may not receive their deliveries. Conservation areas are managed for the appropriate habitat type considering their water priority level and historic shortages decisions. During periods of shortage, there may be a reduction in habitat quality for areas with dense overstory and understory. When insufficient water is available, regardless of cause, to maintain established land cover types as habitat for one or more covered species, the Program Manager would coordinate with the FWS to prioritize

the distribution of available water among created habitats to ensure that the greatest benefits for covered species would be provided. As water becomes available, the conservation areas would be managed to improve conditions. Currently, the Cibola Valley Conservation Area is the only LCR MSCP conservation area with 4th to 6th level priority water rights. Impacts on habitat quality if 4th to 6th level priority water rights may be minimized if groundwater is available to the roots of some or all of the vegetation. Current depth to groundwater in the Cibola Valley Conservation Area is approximately 10 feet.

As described for Lake Powell and Lake Mead, the first decade (2027–2039) exhibits high levels of variability compared with historical conditions for all alternatives, which would result in changes in habitat availability on a larger scale compared with existing conditions, especially for woody riparian habitat (**Figure TA 9-17** and **Figure TA 9-18** in **TA 9**, Vegetation Including Special Status Species). Marsh and woody riparian habitat are modeled to decrease in the first decade in response to increased variability. Wildlife species that are capable of moving longer distances are less likely to be affected by the increased variability. Similar to Lake Mead, in the Hoover Dam to SIB reach wildlife species could experience decreased population levels or localized loss of populations if the increased variability results in increased energy expenditure to find suitable habitat or impacts foraging, breeding, and sheltering behaviors.

Table 3-7
ESA Section 7 Habitat Creation Commitments and Habitat Created 2005–Present

Species	Section 7 Habitat Creation Conservation and Mitigation Commitments (Acres)					LCR MSCP Land Cover Created for the Species (2005–2025) (Acres)
	2004 BO	2018 BO	2022 BO	2024 BO	Total	All[14] Created and Creditable
Yuma Ridgway's rail	512	N/A	15	41	568	362
Southwestern willow flycatcher	4,050	N/A	0	0	4,050	945
Yellow-billed cuckoo	4,050	N/A	0	0	4,050	2,553
Mojave desert tortoise	230 acres of existing habitat protection[15]	N/A	0	0	230	230 acres purchased

In the later decades (2040-2049 and 2050-2060), for the Hoover Dam to SIB reach, all alternatives meet the minimum level of performance in 78 percent or more of futures for marsh habitat (**TA 9**,

[14] Lower Colorado River Multi-Species Conservation Program. 2025. Final Implementation Report, Fiscal Year 2026 Work Plan and Budget, Fiscal Year 2024 Accomplishment Report. Bureau of Reclamation, Boulder City, Nevada. Table 1-8
[15] Net loss in habitat is fully mitigated by protecting 230 acres of desert tortoise habitat in accordance with mitigation requirements in the document entitle "Compensation for Desert Tortoise" (Desert Tortoise Compensation Team 1991).

Vegetation Including Special Status Species, **Figure TA 9-17**). For woody riparian habitat, the Basic Coordination Alternative is the most robust. The impacts on wildlife would be the same as described for Lake Powell and Lake Mead; wildlife would need to adapt to changing habitat conditions at a rate more similar to historical conditions under the Basic Coordination Alternative and would need to adapt to changing habitat conditions on a larger scale for the remaining alternatives. This could impact wildlife through changes in foraging, breeding, or sheltering behaviors, which can impact survival and reproductive rates of individuals. Decreased survival and reproduction on a large scale can have population-level impacts.

Under all alternatives, flows from Hoover Dam to SIB are modeled to decrease under the Average and Dry Flow Categories (**Table TA 3-21** and **Figure TA 3-27** in **TA 3**, Hydrologic Resources). As described in **Section TA 9.2**, Environmental Consequences, in **TA 9**, Vegetation Including Special Status Species, a recent change analysis found that marsh vegetation decreased from 2000 to 2024 (RiverRestoration.org 2025). With a higher level of variability and decreased releases, marsh vegetation is modeled to continue to decrease over time and be replaced by either upland habitat or woody riparian habitat. Wildlife species that use marsh habitat in the Hoover Dam to SIB reach are modeled to experience greater levels of habitat loss than under historical conditions if future conditions are dry or average. This habitat loss could impact wildlife species' ability to forage, breed, nest, and shelter in the area, causing them to relocate or possibly experience reduced survival rates. The potential for decreased water levels in Lake Mead could also result in water with increased temperatures being released from Hoover Dam. This could increase the potential for harmful algal blooms, which impact marsh and woody riparian vegetation, and could impact wildlife directly through increased toxicity exposure or indirectly through reductions in habitat quality and quantity.

Federal, state, and tribal managed habitat areas, such as Cibola National Wildlife Refuge, depend on water from the Colorado River to ensure functional habitat for wildlife. If water in the river drops below the level at which water is able to properly flow through diversion structures or pumps are able to function, there may be impacts on habitat unless another method is used to transport water to the managed habitat areas. If a prolonged period of dryness occurs, woody riparian and marsh vegetation may begin to desiccate; however, the extent to which this will occur is unknown.

Listed threatened and endangered wildlife species that have the potential to occur in the Hoover Dam to SIB analysis area are southwestern willow flycatcher, yellow-billed cuckoo, Yuma Ridgway's rail, northern Mexican gartersnake, and Mojave desert tortoise. Impacts have been previously assessed in the LCR MSCP HCP, 2007 Final EIS, and 2004 SEIS and associated BOs. Additional ESA Section 7 and Section 10 processes are ongoing, and additional impacts will be disclosed in future BOs and HCPs. Migrant and transient southwestern willow flycatchers and yellow-billed cuckoos could be affected by the general availability of woody riparian vegetation in which they forage and shelter, which is modeled to decrease in the first decade (2027–2039) under all alternatives (**Figure TA 9-17** and **Figure TA 9-18** in **TA 9**, Vegetation Including Special Status Species). In the second (2040–2049) and third (2050–2060) decades, decreased cover of woody riparian vegetation is modeled under all alternatives, but to a lesser extent under the Basic Coordination Alternative, CCS Comparative Baseline, and the Representative Preferred Alternative (**Figure TA 9-12** and **Figure TA 9-13** in **TA 9**, Vegetation Including Special Status Species). Breeding southwestern willow flycatchers have been present in recent years at Topock Marsh, while breeding yellow-billed cuckoos are found in LCR

MSCP conservation areas and other restored habitats. Woody riparian vegetation in these areas could be affected by the alternatives if they result in shortage allocation reductions of water deliveries. Alternatives that enhance habitat near established populations would benefit species such as the southwestern willow flycatcher that show fidelity to breeding sites. Reductions in water allocations to the conservation areas could reduce the amount of woody riparian habitat available for yellow-billed cuckoo breeding.

Decreased cover of marsh vegetation may occur in the first decade for all alternatives, which could affect the Yuma Ridgway's rail by reducing the amount of habitat available for breeding, feeding, and sheltering. Under all alternatives, marsh vegetation may reestablish in the second and third decades to an extent similar to recent conditions. However, under dry to average future conditions, water is modeled to decrease over time under all alternatives, which could reduce the amount of habitat available to Yuma Ridgway's rails for breeding, feeding, and sheltering.

The most recent confirmed northern Mexican gartersnake sightings have been in Topock Marsh in the Havasu National Wildlife Refuge. Marsh vegetation at Topock Marsh could be affected by the alternatives if they result in shortage allocation reductions of water deliveries. Northern Mexican gartersnakes are less capable of moving long distances. Should a northern Mexican gartersnake be present in marsh habitat experiencing higher levels of variability that results in the loss of that marsh habitat, as is possible in the first decade under all alternatives, northern Mexican gartersnakes may not be able to find suitable replacement habitat, which could cause local loss of populations. In the second and third decades, all alternatives would have conditions similar to historical conditions, which may support northern Mexican gartersnakes in a manner similar to existing conditions. Mojave desert tortoises are likely to be able to move to upland habitat as the habitat conditions change over time.

Water levels are modeled to decrease under all alternatives under Average and Dry Flow Categories. This may result in additional upland habitat for the Mojave desert tortoise. As at Lake Powell and Lake Mead, the monarch butterfly is likely to find suitable habitat under each alternative and is unlikely to be affected.

Summary Comparison of Alternatives

Changes in reservoir elevations and flow variability can alter the extent and location of marsh, woody riparian, and upland habitats that support terrestrial wildlife, including special status species. These habitat shifts affect wildlife by changing the availability of areas used for foraging, breeding, sheltering, and migration. While highly mobile species may relocate to suitable habitat, less mobile species may experience reduced survival or reproduction if habitat availability declines or becomes fragmented, which can reduce population sizes or lead to the loss of local wildlife. For Lake Powell, the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative would result in wildlife habitat availability most similar to historical conditions (**Table TA 9-1** in **TA 9**, Vegetation Including Special Status Species). The Maximum Operational Flexibility Alternative would also result in wildlife habitat availability most similar to historical conditions for Lake Mead. However, for Hoover Dam to the SIB, the Maximum Operational Flexibility Alternative and Enhanced Coordination Alternative would result in wildlife habitat availability least similar to historical conditions, with subsequent impacts on wildlife foraging, breeding, or sheltering behaviors, which can reduce reproduction and survival of individuals. Similarly, the Basic Coordination Alternative would result in wildlife habitat least similar to historical conditions for Lake Powell, but it would be closest to historical conditions for Lake Mead

and Hoover Dam to the SIB. Therefore, no single alternative would result in wildlife habitat availability similar to historical conditions across all reaches. For all reaches, multiple alternatives provide variability more similar to historical conditions than the CCS Comparative Baseline except for the Hoover Dam to SIB reach, where only the Basic Coordination Alternative would result in variability more similar to historical conditions for woody riparian vegetation. This suggests that a change in management from current strategies would benefit a large portion of the analysis area but would not benefit woody riparian vegetation in the Hoover Dam to SIB reach unless the Basic Coordination Alternative was selected.

Under all alternatives, the first decade (2027–2039) would experience more variability, which would likely result in a reduction in marsh and woody riparian habitat and, therefore, an increase in impacts on wildlife compared with historical conditions. All alternatives would see conditions return closer to historical conditions in the second decade (2040–2049) and third decade (2050–2060), which would likely result in wildlife habitat reestablishing to a similar extent. Where variability eliminates or prevents the establishment of marsh, woody riparian, or upland habitat, there may be a shift to one of the other habitat types.

For the Glen Canyon Dam to Lake Mead reach, the alternative that would result in wildlife habitat availability most similar to historic conditions depends strongly on flow categories. Under the Dry Flow Category and Critically Dry Flow Category, some differences among the alternatives emerge, presumably because there are greater differences in the lowest flows, the median flows, and peak flows under those conditions. However, across all alternatives, all sub-reaches, and all evaluated criteria (suitable habitat area, native species richness, proportion of native species cover, and annual total vegetation cover), the interquartile ranges of the alternatives often overlap. When the interquartile ranges overlap, it is difficult to say whether one alternative is truly different from another. Therefore, no single alternative emerged as the best or worst for retaining wildlife habitat similar to historic conditions.

For all reaches, a decrease in water elevation or flow could increase water temperatures, which would increase the potential for harmful algal blooms. Harmful algal blooms can cause direct impacts on wildlife through increased toxicity or indirect impacts through decreases in habitat quality and quantity. Under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative, there would be increased water levels in Lake Powell in all but the Critically Dry Flow Category, which would result in the lowest potential for harmful algal blooms. For Lake Mead, all alternatives may result in a lowered elevation, which could increase the potential for harmful algal blooms in Lake Mead and in the Hoover Dam to SIB reach.

3.11 Cultural Resources

3.11.1 Affected Environment

Cultural resources are the physical evidence of past or present cultures, including archaeological sites, historic-era buildings and structures, objects, trails, landforms, and other places of traditional, cultural, or religious importance. Cultural resources can be human-made or natural features and are, for the most part, unique, finite, and nonrenewable.

A Class I cultural resources record search was conducted for the study area in Arizona, California, Nevada, and Utah (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi 2024). Reclamation is consulting with the Arizona, California, Nevada, and Utah State Historic Preservation Officers (SHPOs), land managing agencies, affected tribes, and other consulting parties to develop a project-specific programmatic agreement under Section 106 of the NHPA and its implementing regulations (36 CFR 800.14). As part of the development of the programmatic agreement, Reclamation, the SHPOs, land managing agencies, affected tribes, and other consulting parties have defined the area of potential effect (APE). For this analysis, the NEPA study area coincides with the APE which also follows the Class I search area.

The study area for the analysis runs from the northern extent of Lake Powell to the SIB and consists of the Colorado River channel from bank to bank except from Glen Canyon Dam to Lake Mead, where it stretches from canyon rim to canyon rim, as well as a 0.5-mile buffer on either side of the riverbank or canyon rim. For additional information on regulatory considerations, including a detailed summary of Section 106 of the National Historic Preservation Act and its implementing regulations under 36 CFR 800, please reference **Section TA 11.1**, Affected Environment, in **TA 11**, Cultural Resources.

Identification Efforts

The Class I records search identified archaeological resources, built environment resources, specially designated cultural resources (National Historic Landmarks [NHLs], National Heritage Areas [NHAs], and National Historic Trails [NHTs]), cultural landscapes, and traditional cultural places (TCPs) within the study area. For additional information on data sources and the types of data collected for each state in the study area, please reference **Section TA 11.1.1**, Identification Efforts, in **TA 11**, Cultural Resources. The Class I records search shows that much of the study area has not been surveyed for cultural resources. Because survey coverage for both Lake Powell and Lake Mead is very low, there is potential for additional undocumented sites to exist in the study area. Data were compiled in August 2023, and the 2023 datasets were incorporated into the analysis. Additionally, the NPS provided updated archaeological site counts for Lake Powell and Lake Mead (including Grand Canyon-Parashant NM) in March 2026, which supplemented the August 2023 dataset for the reservoirs. Therefore, the site counts used in the analysis do not reflect later agency database updates in the study area outside the reservoirs.

This section analyzes impacts on archaeological sites, built environment resources, and specially designated cultural resources. Impacts on tribal resources, tribal perspectives on cultural landscapes, and TCPs are analyzed in **TA 13**, Tribal Resources.

Class I Results

The results of the Class I records search, as summarized below, include archaeological and built environment resources as well as specially designated cultural resources identified in the study area by state. For a more detailed summary on the results of the comprehensive Class I records search for each state, please reference **Section TA 11.1.4**, Class I Results, in **TA 11**, Cultural Resources.

Survey coverage of the study area is variable by state but is overall very low, ranging from 2 or 3 percent in Arizona, 5 percent in Nevada, 11 percent in California, and 37 percent in Utah. Because of the low coverage, the numbers of archaeological sites presented below do not reflect the total number

of sites in the study area and are likely only a small fraction of the sites that are present. However, the sites that have been recorded give an overall picture of resources that may be found in the study area and are used in the analysis as a representative data set for what may be present in unsurveyed areas.

Arizona

The 2023 Class I records search initially identified a total of 4,246 archaeological sites in the study area in Arizona. This number included both NPS and non-NPS data, accounting for duplicates between the two datasets (see **Table TA 11-1** in **TA 11**, Cultural Resources). Non-NPS data contained 1,246 previously recorded sites in the study area. The updated site counts provided by NPS in March 2026 totaled 4,135 sites, which includes sites that overlap from the non-NPS dataset (see **Table TA 11-1** and **Table TA 11-3** in **TA 11**, Cultural Resources). The NPS dataset represents a wide range of cultural affiliations and site functions across three NPS park units (GCNP, Lake Mead NRA, and Glen Canyon NRA) (see **Table TA 11-4** and **Table TA 11-5** in **TA 11**, Cultural Resources). For the built environment, 49 previously evaluated resources were identified in the study area in Arizona. Of these, 43 are listed in the National Register of Historic Places (NRHP); these non-NHL resources consist of 8 districts (that is, groupings of resources), 26 buildings, 6 structures, 1 object, and 2 sites. The remaining 6 resources, all districts, are NRHP-eligible (see **Table TA 11-13** in **TA 11**, Cultural Resources). Additionally, 16 unevaluated but notable built environment resources (5 districts, 1 building, 9 structures, and 1 site) were also identified and may be eligible for the NRHP based on extensive research conducted for the Class I records search (see **Table TA 11-14** in **TA 11**, Cultural Resources).

Specially designated cultural resources identified in the study area in Arizona include nine NHLs, most of which are in GCNP, along with Hoover Dam NHL (also in Nevada) and Yuma Crossing NHL (also in California). Yuma Crossing NHL also encompasses the Yuma Crossing NHA (the only NHA identified in the study area), which is only on the Arizona side of the Colorado River. The Armijo Route of the Old Spanish NHT corridor (also in Utah and Nevada), the Juan Bautista de Anza NHT corridor, and the recently designated Butterfield Overland NHT corridor (both of which also cross into California) also cross the study area in Arizona, although there is no known physical evidence of any of these trails (see **Table TA 11-18** in **TA 11**, Cultural Resources).

California

A total of 493 previously recorded archaeological sites are found within the study area in California (see **Table TA 11-6** in **TA 11**, Cultural Resources) along with 63 built environment resources (three districts, a regional park, and various buildings, structures, roads, and transmission lines) (see **Table TA 11-15** and **Table TA 11-16** in **TA 11**, Cultural Resources). Yuma Crossing NHL is the only NHL in the study area in California, and there are no NHAs because the Yuma Crossing NHA designation only includes portions of the NHL on the Arizona side of the river. For the portions of the Juan Bautista de Anza NHT and Butterfield Overland NHT that cross the study area in California, there is no physical evidence of original trail segments known to exist in the study area.

Nevada

In the Nevada study area, 664 archaeological sites have been previously recorded in the NPS and non-NPS datasets (99 non-NPS [Nevada Cultural Resources Inventory System only] and 565 NPS) (see **Table TA 11-7** and **Table TA 11-8** in **TA 11**, Cultural Resources). Research identified 159 previously documented built environment resources (districts, individual buildings, structures, sites, and objects),

of which 98 are associated with the construction and ongoing operation of the NRHP-listed Hoover Dam Historic District (also an NHL) on the Nevada side of the Colorado River. In addition to those resources associated with Hoover Dam, there is 1 NRHP-listed structure in Lake Mead NRA (Willow Beach Gauging Station), 26 associated with the development of recreation around Lake Mead and Lake Mohave within Lake Mead NRA, and 3 associated with Davis Dam. The remaining 29 built environment resources include 23 documented on an individual basis (apart from Hoover and Davis Dams and established recreation areas in Lake Mead NRA) and 6 for which no information was available from corresponding archives (see **Table TA 11-17** in **TA 11**, Cultural Resources). Hoover Dam NHL (also in Arizona) and the Mojave Road route of the Old Spanish NHT corridor (also in Arizona and Utah) are the only two specially designated cultural resources in the study area in Nevada. There is no evidence of the Old Spanish NHT identified in the study area.

Utah

A total of 1,384 previously recorded archaeological sites (366 non-NPS and 1,018 NPS) were identified in the study area in Utah (see **Table TA 11-10** and **Table TA 11-11** in **TA 11**, Cultural Resources) along with one built environment resource (NRHP-eligible Hite Crossing Bridge). The Armijo Route of the Old Spanish NHT corridor is the only specially designated cultural resource in the study area in Utah, and, like other NHT corridors, there are no known segments of original trail identified in the study area.

3.11.2 Environmental Consequences

Impacts on cultural resources could result from changes in lake levels or river flows from the annual releases. Direct impacts, which are those immediate in place and time, could occur from processes like wave action or wet-dry cycling, and also include visual, auditory, and atmospheric impacts. Indirect impacts occur later in time and/or farther away in terms of distance and could include easier access to newly exposed archaeological sites that were previously underwater. Impacts on cultural resources analyzed in this section only include those impacts resulting from Reclamation's management of annual releases from Glen Canyon and Hoover Dams, which influence reservoir elevations, river flows, and aeolian (wind-borne) transport. The analysis emphasizes cultural resources within 20 meters (66 feet) of the river corridor because they are the most likely to be affected by changes in river flows.

Methodology

Archaeological Resources

Potential impacts on archaeological resources were evaluated using three approaches: 1) site counts (by elevation) compared to modeled lake levels; 2) a USGS/NPS-developed preservation risk model (Caster et al. 2026); and 3) a USGS aeolian (wind-blown sand) transport model (Kelley et al. 2026; Salter and Grams 2026). Elevations for all sites identified in the Class I records search at Lake Powell and Lake Mead were calculated and used to identify those sites that are at elevations subject to changes in water levels. However, due to the low Class III survey coverage, there are doubtless more sites to be found. Along the river corridor, the analysis considers sites identified within 20 meters (66 feet) of the river corridor (bank to bank). A 20-meter (66-foot) distance is used because the variability of elevation along the river corridor is too great to efficiently sort thousands of sites by elevation. For additional information on these methods, as well as the development of the preservation risk model and the models for wind-deposited sediment, please reference **Section TA 11.2.1**, Methodology, in **TA 11**, Cultural Resources.

Built Environment Resources

Because built environment resources are generally less vulnerable to operational impacts than archaeological resources, which are finite, fragile, and nonrenewable, no modeling was conducted specifically for built environment resources. The primary built environment resources identified in the study area consist of major water management infrastructure constructed as part of Reclamation projects like Glen Canyon Dam, Hoover Dam, and Davis and Parker Dams as well as the smaller dams and the various canals and levee systems in the lower reaches of the Colorado River. These facilities represent critical infrastructure essential to Colorado River operations. None of the alternatives would involve decommissioning, removal, or substantial alteration of these facilities. Accordingly, implementation of the alternatives would not be expected to affect the historic integrity or significance of these resources. Based on this assessment, no direct or indirect impacts are anticipated on built environment resources constituting critical water management facilities, and they are not carried forward for detailed analysis.

There are also built environment resources around the reservoirs and immediately along the river corridor—particularly those developed in response to the creation of Lake Powell and Lake Mead or to provide access to or means across the river in the Grand Canyon—that are not considered critical infrastructure for river operations. As such, these types of properties were designed or located in consideration of fluctuating water levels around both the reservoirs and the river corridor. Therefore, impacts on NRHP-listed or -eligible built environment resources would occur where uncharacteristic water levels and river flows exceed historical ranges. For additional information on methodology for built environment resources, please reference **Section TA 11.2.1**, Methodology, in **TA 11**, Cultural Resources.

Specially Designated Cultural Resources

No modeling was undertaken for NHLs, NHAs, or NHTs. The one NHA identified in the study area (Yuma Crossing) coincides with the Arizona portion of the Yuma Crossing and Associated Sites NHL; therefore, it is analyzed as an NHL. There are no confirmed segments of original trail in the study area for the three NHTs. Impacts on NHLs, as the only specially designated cultural resources identified in the study area, could occur only if river flows are outside the historical range.

Impact Analysis Area

The impacts analysis area consists of the Colorado River corridor from the upper limits of Lake Powell in Utah through the Grand Canyon in Arizona and Lake Mead in Arizona, and from Hoover Dam to the SIB.

Assumptions

- Once a resource has been inundated by a reservoir, being continuously inundated thereafter is more conducive to preservation than repeated cycles of inundation and exposure (that is, wet-dry cycling and wave action).
- Repeating cycles of inundation and exposure of resources by the reservoirs or the river are damaging to archaeological resources.
- The covering of resources by wind-deposited river-sourced sediment is conducive to preservation.

- While HFEs were considered in the aeolian transport model as part of the individual vegetation and sandbar models, actual HFE frequency may differ from that assumed or predicted in the modeling.
- Impacts on cultural resources can be characterized based on projected minimum and end-of-year lake elevations for very wet through very dry conditions and river flow volumes.
- Cultural resources that have not been previously inundated would not be inundated under the CCS Comparative Baseline, the No Action Alternative, or any action alternatives (that is, no cultural resources located above reservoir spillway elevations or above the levels of current river flows would be inundated).
- The limit of physical impacts on cultural resources by the river is constrained to resources within the river corridor (bank to bank) or within 20 meters (66 feet) of the river.
- Where previous survey coverage is absent within the study area, there may be sites that have not yet been identified that could be affected under the CCS Comparative Baseline, the No Action Alternative, or the action alternatives.
- The Class I records search conducted for the study area in Arizona, California, Nevada, and Utah serves as a representative dataset for the purposes of analysis.
- Lake Mohave and Lake Havasu would continue to follow their target end-of-the-month elevation schedules ("rule curve") (see **TA 3**, Hydrologic Resources), therefore, no cultural resource impacts are expected at these reservoirs.

Impact Indicators

- Projected monthly and end-of-year lake elevations that may expose cultural resources to damage from wave action, wet-dry cycling, or increased ease of access
- Projected WY and CY dam releases resulting in potential river-flow changes that leave cultural resources susceptible to damage from erosion, wet-dry cycling, or increased ease of access
- Projected availability of sediments along the river that may be transported by wind and deposited on archaeological sites

Issue 1: How will any changes in dam operations affect (1) lake elevations at Lake Powell and Lake Mead and (2) river flows downstream, which may affect cultural resources?

Lakes

This section summarizes the potential for archaeological resources to be exposed and, therefore, experience potential impacts from exposure, using the distribution of previously recorded archaeological sites by elevation and the hydrologic modeling results for Lake Powell and Lake Mead elevations. The following summary incorporates the discussion of hydrologic modeling as presented in **TA 3**, Hydrologic Resources. For additional information on the technical details related to Issue 1, please reference **Section TA 11.2.2**, Issue 1, in **TA 11**, Cultural Resources.

Because survey coverage varies across the study area and much of the site location data was recorded prior to modern GPS/GIS technology, precise site counts are not feasible for analysis. Site counts therefore represent a sample used to characterize the overall level of sensitivity within the study area. Representative site counts by elevation were compiled from Class I data using associated elevations based on critical conditions for each lake. For Lake Powell, the critical elevations considered for the

analysis are 3,700 feet (the top of the Glen Canyon Dam spillway) to 3,490 feet (the minimum power pool) (see **Table TA 3-2** in **TA 3**, Hydrologic Resources). For Lake Mead, these associated elevations are 1,221 feet (the top of the Hoover Dam Spillway) down to 950 feet (the minimum power pool) (see **Table TA 3-5** in **TA 3**, Hydrologic Resources). Archaeological sites identified in the Lake Powell and Lake Mead dataset were distributed by elevation range (see **Table TA 11-19** and **Table TA 11-20** in **TA 11**, Cultural Resources). Overall, survey coverage for both lakes is very low (around 3 percent), which means the numbers in these tables greatly underrepresent the total number of sites present. There are no NRHP-listed or NRHP-eligible built environment resources within the elevation range for Lake Powell (3,700–3,490 feet). There is one NRHP-eligible district (Echo Bay Developed Area) within the elevation range for Lake Mead (1,221–950 feet); its historic boat ramp falls between 1,221 and 1,100 feet.

The analysis for both Lake Powell and Lake Mead as presented here focuses on average and dry to critically dry flow conditions (Average, Dry, and Critically Dry Flow Categories). For discussion related to wet flow conditions (Wet Flow Category), please refer to **TA 11.2.2**, Issue 1, in **TA 11**, Cultural Resources.

Lake Powell

This section references **Figure TA 3-6** in **TA 3.2.1**, Issue 1, and **Tables TA 3-3** and **TA 3-4** at the end of **TA 3**, Hydrologic Resources. The following discussion uses the known number of sites within the Lake Powell dataset provided by NPS staff (see **Table TA 11-19** in **TA 11**). Survey coverage at Lake Powell is calculated to be 3.3 percent of the area below full pool, meaning the number of sites in the Lake Powell data set represents a fraction of the total number of sites present. For additional information on these tables and figures as they were incorporated into the analysis of cultural resources, please reference **Section TA 11.2.2**, Issue 1, in **TA 11**, Cultural Resources.

In general, when the level of Lake Powell is at the top of the Glen Canyon Dam spillway (3,700 feet), all 857 archaeological sites in the Lake Powell dataset (as well as any undiscovered sites below this elevation) would be inundated. Conversely, water levels dropping to minimum power pool could expose up to all 857 archaeological sites (depending on how many of those in the Lake Powell dataset remain above 3,490 feet), leaving them vulnerable to impacts. Again, it is important to note that, because some areas at Lake Powell have not been surveyed, all of the modeled scenarios have the potential to impact undiscovered archaeological resources. Sites exposed at higher elevations may be less vulnerable to impacts from wet-dry cycling and wave action, but ease of access to them may increase depending on their location. Elevations for Lake Powell are assessed based on minimum WY and EOWY elevations.

Under the Average Flow Category, the modeled scenarios begin to diverge in performance. Minimum WY median elevations for the CCS Comparative Baseline and the No Action Alternative fall around and just below 3,550 feet, potentially exposing at least 316 known archaeological sites, along with any undiscovered sites, within and above the 3,540–3,560-foot zone. EOWY median elevations for the CCS Comparative Baseline and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) are around 3,570 feet, while the No Action Alternative is just above 3,580 feet. At these elevations, at least 280 known sites, along with any undiscovered sites above 3,570 feet within the 3,580–3,560-foot zone, could be vulnerable if water levels drop. The Basic Coordination and Representative Preferred Alternatives perform somewhat better, with minimum WY median elevations

of approximately 3,560 feet and 3,570 feet, respectively, potentially exposing up to 316 known sites. The EOWY median elevations are higher at around 3,590 feet for the Basic Coordination Alternative and just below 3,600 feet for the Representative Preferred Alternative, potentially exposing at least 249 known sites and any additional sites above 3,590 feet within the 3,600–3,580-foot zone.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best under average conditions. Minimum WY median elevations are around 3,610 feet and 3,600 feet, respectively, which would expose between 197 and 249 known sites. EOWY median elevations are around 3,630 feet for the Enhanced Coordination Alternative and 3,620 feet for the Maximum Operational Flexibility Alternative. At these elevations, the Enhanced Coordination Alternative could expose at least 138 known sites (plus any sites above 3,630 feet within the 3,640–3,620-foot zone), while the Maximum Operational Flexibility Alternative could expose up to 197 known sites. These two alternatives also have the narrowest interquartile ranges for both median elevation metrics. Additional sites would be exposed as water levels decline further and conditions become drier, depending on site elevation.

For the Critically Dry Flow Category, the CCS Comparative Baseline, the No Action Alternative, and the action alternatives struggle to maintain key Lake Powell elevations. Minimum WY and EOWY median elevations for the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives fall below 3,490 feet (minimum power pool), with the No Action Alternative declining to just below 3,440 feet. Under these conditions, at least 415 known archaeological sites (approximately 48 percent of the Lake Powell dataset) along with any undiscovered sites, could be exposed and vulnerable. Additional sites may be affected as elevations fall below 3,490 feet, depending on the distribution of the 442 recorded sites below 3,500 feet. The 3,500 foot elevation is important because it provides an approximate 10-foot buffer to protect critical infrastructure, water supply, and hydropower operations, which are critically impacted at an elevation of 3,490 feet (see **Section TA 3.2.1**, Issue 1, in **TA 3**, Hydrologic Resources).

The Representative Preferred Alternative performs slightly better under critically dry conditions, with a minimum WY median elevation just above 3,490 feet. This would still leave at least 415 known sites exposed above 3,500 feet but could protect additional sites if present above the minimum power pool elevation. The EOWY median elevation for this alternative is just below 3,510 feet, which would inundate more sites below this level within the 3,520–3,500-foot zone. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform the best compared to the others. Minimum WY median elevations are approximately 3,520 feet and 3,510 feet, respectively, with EOWY median elevations around 3,560 feet and 3,550 feet. Relative to these EOWY elevations, both alternatives could expose at least 316 known sites and any undiscovered sites down to around 3,560 feet, with the Maximum Operational Flexibility Alternative potentially exposing additional sites above 3,550 feet within the 3,560–3,540-foot zone. Interquartile ranges for the Enhanced Coordination Alternative indicate that it has the greatest potential to limit site exposure under critically dry conditions, with the upper bound of the EOWY median elevation (75th percentile) reaching approximately 3,600 feet and potentially limiting exposure to 249 known sites.

Lake Mead

This section references **Figure TA 3-11** in **TA 3.2.1**, Issue 1, and **Tables TA 3-6** and **TA 3-7** at the end of **TA 3**, Hydrologic Resources. The following discussion uses the known number of sites within

the Lake Mead dataset provided by NPS staff. Survey coverage at Lake Mead is calculated to be 2.8 percent of the area below full pool meaning the number of sites in the Lake Mead data set represents a fraction of the total number of sites present. For additional information on these tables and figures as they were incorporated into the analysis of cultural resources, please reference **Section TA 11.2.2**, Issue 1*,* in **TA 11**, Cultural Resources.

In general, when water-level elevations are at or above 1,221 feet, all 310 archaeological sites in the dataset would be inundated. Conversely, if water levels drop to 950 feet, all 310 sites in the Lake Mead dataset would be exposed, depending on the elevations of sites below 961 feet (see **Table TA 11-20** in **TA 11**, Cultural Resources). Because very little of Lake Mead was surveyed prior to the construction of Hoover Dam in the early 1930s and, as a result, undiscovered archaeological resources are likely to be present in unsurveyed areas, such resources could be affected under any of the modeled scenarios. Elevations for Lake Mead are assessed based on minimum CY and EOCY elevations.

Under the Average Flow Category, the modeled scenarios begin to diverge in performance with respect to minimum CY and EOCY median elevations. As lake levels decline, additional sites may be exposed depending on elevation. The No Action Alternative performs the most poorly, with minimum CY and EOCY median elevations just below 970 feet and just below 980 feet, respectively. These elevations would expose at least 301 known archaeological sites in the Lake Mead dataset as well as sites below this elevation within the 981–961-foot zone, including any undiscovered sites that may be present. The CCS Comparative Baseline performs somewhat better than the No Action Alternative, with a minimum CY median elevation of about 1,030 feet and an EOCY median elevation around 1,040 feet. However, these elevations could still leave at least 286 known archaeological sites, along with any undiscovered sites present, vulnerable to impacts from exposure. The Basic Coordination Alternative has a minimum CY median elevation just above 1,050 feet and an EOCY median elevation just above 1,060 feet, leaving at least 280 known archaeological sites (and any undiscovered sites present) exposed. The corresponding interquartile ranges, from approximately 1,130 feet at the upper limit down to around 1,000 feet, could leave between 227 and 296 known sites vulnerable to impacts from exposure, depending on elevation.

The Representative Preferred Alternative performs slightly better, with a minimum CY median elevation just above 1,090 feet and an EOCY median elevation just above 1,100 feet, potentially exposing at least 265 known archaeological sites along with any undiscovered sites present. The Enhanced Coordination Alternative has a minimum CY median elevation around 1,100 feet and an EOCY median elevation around 1,110 feet, which could expose between 245 and 265 known sites, depending on elevation. The interquartile ranges for this alternative are similar for both minimum CY and EOCY elevations, ranging from around 1,130 feet down to about 1,060 feet and from around 1,140 feet down to around 1,070 feet, respectively. Within these ranges, between 227 and 280 known sites could be exposed, depending on elevation and the presence of undiscovered sites. The Maximum Operational Flexibility Alternative has a minimum CY median elevation just below 1,120 feet and an EOCY median elevation just below 1,130 feet, potentially exposing between 227 and 245 known sites, along with any undiscovered sites present. The interquartile range for this alternative is the largest among the modeled scenarios, ranging from around 1,180 feet, which could leave up to 142 known sites exposed, down to just above 1,040 feet, which could expose up to 286 known archaeological sites and any undiscovered sites also present above these elevations.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the best under average hydrological conditions. The LB Priority approach has minimum CY and EOCY median elevations around 1,140 feet and 1,150 feet, respectively, which could expose between 196 and 227 known sites as well as any undiscovered sites present. The LB Pro Rata approach performs slightly better, with a minimum CY median elevation just above 1,150 feet and an EOCY median elevation around 1,160 feet. These elevations could expose at least 196 known sites as well as sites present above 1,150 feet within the 1,161–1,141-foot zone. Interquartile ranges for the Supply Driven Alternative vary, with the LB Pro Rata approach ranging from just below 1,190 feet (75th percentile) to just below 1,070 feet (25th percentile), and the LB Priority approach ranging from around 1,180 feet (75th percentile) to just below 1,060 feet (25th percentile). Within these ranges, between 85 and 275 known sites could be exposed under the LB Pro Rata approach and between about 142 and 280 known sites under the LB Priority approach, depending on elevation and the presence of undiscovered sites.

As hydrological conditions become critically dry, the modeled scenarios maintain the same relative performance but shift downward collectively by roughly 100 feet in elevation within the Critically Dry Flow Category. For Lake Mead, the 975-foot elevation is important because it provides a 25-foot buffer for water supply and hydropower to stay above minimum power pool (see **Section TA 3.2.1**, Issue 1, in **TA 3**, Hydrologic Resources). Under these conditions, the elevation at which sites are vulnerable to wet-dry cycling and wave action would be lowest across all scenarios. The CCS Comparative Baseline has a minimum CY median elevation around 930 feet, while the No Action Alternative declines further to around 900 feet, both well below the Lake Mead minimum power pool elevation of 950 feet. The EOCY median elevation for the CCS Comparative Baseline is around 960 feet, while the No Action Alternative declines to around 930 feet. At these elevations, up to all 310 known archaeological sites in the Lake Mead dataset, along with any undiscovered sites that may be present, could be exposed depending on the elevations of the four known sites below 961 feet. The Basic Coordination Alternative performs somewhat better, with a minimum CY median elevation just above 970 feet and an EOCY median elevation around 980 feet. The Representative Preferred Alternative performs slightly better, with a minimum CY median elevation around 980 feet and an EOCY median elevation just above 990 feet. Despite these slightly higher elevations, both alternatives could still leave at least 296 known sites (more than 95 percent of the sites in the Lake Mead dataset) along with any undiscovered sites present, exposed during critically dry conditions.

The Enhanced Coordination Alternative has minimum CY and EOCY median elevations around or just above 1,000 feet, with interquartile ranges extending from approximately 1,050 feet down to around 950 feet. Depending on the elevations of the four known sites below 961 feet, this alternative could still leave up to all 310 known sites exposed. The Maximum Operational Flexibility Alternative has similar median elevations, with minimum CY and EOCY values just above 1,010 feet and around 1,000 feet, respectively. These elevations could leave between 291 and 296 known sites (and any undiscovered sites) vulnerable to impacts. The interquartile ranges extend from around 1,060 feet down to approximately 970 feet, potentially exposing between about 280 and 301 known sites depending on the elevations of sites within the 981–961-foot zone.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) also performs slightly better compared to other scenarios. The LB Priority approach has minimum CY and EOCY median elevations around 1,010 feet, while the LB Pro Rata approach reaches the highest median elevations under critically dry conditions at or just below approximately 1,030 feet. Even so, between 286 and 291

known sites could still be exposed based on median elevations. Examination of the upper limits of the interquartile ranges indicates that some additional sites could remain inundated, with upper elevations around or just above 1,070 feet for the LB Priority approach (potentially exposing at least 275 known sites) and around 1,090 feet for the LB Pro Rata approach (potentially exposing at least 265 known sites). However, both scenarios would still leave at least 85 percent of the archaeological sites in the Lake Mead dataset, along with any undiscovered sites present, exposed above the water level and therefore vulnerable to impacts.

For the Echo Bay Developed Area, modeled scenarios with minimum CY and EOCY median elevations below 1,100 feet would expose portions of the boat ramp; however, this exposure would occur outside the NRHP-eligible district boundary. Modeled scenarios with elevations above 1,100 feet could partially inundate the ramp, with full submersion occurring at higher elevations along the ramp, which extends up to approximately 1,221 feet. These conditions would be more likely under the Supply Driven Alternative because the interquartile ranges for minimum CY and EOCY elevations under the LB Priority approach extend up to around 1,090 feet. Reservoir elevations exceeding 1,221 feet could affect recreation area infrastructure within the district boundary.

Preservation Risk Modeling

Preservation risk modeling results were compared with the 90th percentile values of modeled values for WY 2008 to 2025 (i.e., the 2007 Interim Guidelines period); the 90th percentile risk value is 2.72 for Lake Powell and 2.24 for Lake Mead (see **Figure TA 11-1** in **TA 11**, Cultural Resources; Caster et al. 2026). If preservation risk exceeds these threshold values, impacts on archaeological sites may occur at levels beyond those expected under historical conditions for the specific reservoir. For the purposes of this analysis, "historical conditions" coincide with the 2007 Interim Guidelines period (WY 2008–2025).

For Lake Powell under the Average Flow Category, the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have preservation risk median values at the 2.72 threshold. The Representative Preferred Alternative has a slightly lower median value of 2.69, followed by the Maximum Operational Flexibility Alternative at 2.65 and the Enhanced Coordination Alternative at 2.52. The Maximum Operational Flexibility and Enhanced Coordination Alternatives share the same interquartile range, from 2.65 (75th percentile) to 2.24 (25th percentile), under average hydrological conditions. The Representative Preferred Alternative has the narrowest interquartile range, from 2.72 to 2.65, while the No Action Alternative shows the greatest variation, ranging from 3.23 to 2.24. Overall, under average modeled conditions, preservation risk values generally remain at or near the 2.72 threshold, indicating that impacts on archaeological sites, if they occur, would not exceed those expected under similar average conditions historically.

Under the Critically Dry Flow Category for Lake Powell, preservation risk median values for the CCS Comparative Baseline and all alternatives exceed the 2.72 threshold. The No Action Alternative has the highest median preservation risk value at 3.71, followed by the Basic Coordination Alternative at 3.42 and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at 3.39. The Representative Preferred Alternative has a median value of 3.23, while both the Maximum Operational Flexibility and Enhanced Coordination Alternatives have median values of 3.10; however, the interquartile range for the Enhanced Coordination Alternative drops to 2.71 at the lower bound. Because lower preservation risk values indicate better performance, median values below 2.72 would

suggest impacts comparable to historical conditions. Under critically dry conditions, however, all median values exceed this threshold, indicating elevated preservation risk relative to historical conditions.

For Lake Mead under the Average Flow Category, the No Action Alternative has the highest preservation risk median value at 2.70. The CCS Comparative Baseline follows at 2.31, and the Basic Coordination Alternative at 2.26, both above the Lake Mead preservation risk threshold of 2.24, indicating greater risk to archaeological sites than would be expected under similar historical conditions. The Enhanced Coordination Alternative has a median value just below the threshold at 2.22, followed by the Representative Preferred Alternative at 2.20 and the Maximum Operational Flexibility Alternative at 2.18. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the lowest median preservation risk value at 2.03. Interquartile ranges for the CCS Comparative Baseline, the No Action Alternative, and all action alternatives extend above the 2.24 threshold, including the Representative Preferred Alternative at 2.31. The lower bounds of these ranges generally fall below the threshold, except for the No Action Alternative, which remains above it at 2.35.

Under the Critically Dry Flow Category for Lake Mead, preservation risk median values for all scenarios exceed the 2.24 threshold. The No Action Alternative performs the worst with a median value of 3.07, followed by the CCS Comparative Baseline at 3.00. All action alternatives have lower median values but remain above the threshold, including the Basic Coordination Alternative at 2.64, the Representative Preferred Alternative at 2.38, the Enhanced Coordination Alternative at 2.36, and both the Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives at 2.35. Because none of the scenarios fall below the 2.24 threshold, impacts on archaeological sites under critically dry conditions would exceed those anticipated under similar historical conditions.

Figure TA 11-2 and **Figure TA 11-3** in **TA 11**, Cultural Resources, compare alternatives by showing the percentage of futures in which the preservation risk is below 2.72 for Lake Powell and 2.24 for Lake Mead in at least 90 percent of months. The 2.72 and 2.24 preservation risk values represent the 90th percentile of modeled historical values for WY 2008–2025 (the 2007 Interim Guidelines period), which includes the period of significant reservoir storage loss. To reiterate, if the preservation risk is above those values, impacts on archaeological sites may be greater than expected under historical conditions.

For Lake Powell, over the full modeling period, the Enhanced Coordination Alternative would be the most robust, meeting the 2.72 risk threshold in 47 percent of futures. The Maximum Operational Flexibility Alternative would be less robust, meeting the 2.72 threshold in 28 percent of futures, followed by the No Action and Basic Coordination Alternatives at 17 percent, the Representative Preferred Alternative at 16 percent, and the CCS Comparative Baseline at 15 percent. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meets the preferred level of performance in 14 percent of futures. This relational pattern is consistent if the full modeling period is broken out into shorter periods, including the first decadal period from 2027–2039 where the Enhanced Coordination Alternative also performs the best at 30 percent whereas the CCS Comparative Baseline performs the worst at 10 percent. It is important to note that 2027, as the beginning of the first 10-year interval, is anticipated to have low reservoir elevations and, therefore, the

modeling for this breakout (2027–2039) shows very low percentages of futures met for the preferred minimum of performance across the CCS Comparative Baseline, the No Action Alternative, and all other action alternatives. See **Figure TA 11-2** in **TA 11** (Cultural Resources) for robustness modeled for 2040–2049 and 2050–2060 at Lake Powell.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would be the most robust by meeting the 2.24 risk threshold in 24 percent of futures over the full modeling period. The CCS Comparative Baseline and No Action Alternative meet the preferred minimum of performance in only 6 and 13 percent of futures, respectively. The Maximum Operational Flexibility Alternative would meet the threshold in 19 percent of futures, followed by the Enhanced Coordination Alternative at 15 percent, the Representative Preferred Alternative at 14 percent, and the Basic Coordination Alternative at 10 percent. If the modeling period is broken out, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can be seen to meet the threshold for only 5 percent of futures in the first decadal period (2027–2039), followed by the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative, and the Representative Preferred Alternative, all three of which meet the preferred level of performance in only 3 percent of futures. The Basic Coordination and Enhanced Coordination Alternatives meet the threshold 2 percent of the time while the No Action Alternative is at 1 percent for the 2027–2039 modeling period. See **Figure TA 11-3** in **TA 11** (Cultural Resources) for robustness modeled for 2040–2049 and 2050–2060 at Lake Mead.

Overall, the Enhanced Coordination Alternative is the most robust for Lake Powell for the full modeling period and the first decadal modeling period (2027–2039), followed by the Maximum Operational Flexibility Alternative. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust, followed by the Maximum Operational Flexibility Alternative for the full modeling period. Looking at only the 2027–2039 modeling period, while the Supply Driven Alternative (both LB Priority and Pro Rata approaches) still remains the most robust at 5 percent, the CCS Comparative Baseline, Representative Preferred Alternative, and Maximum Operational Flexibility Alternative are all equally, but lesser, robust for the first 10-year period at 3 percent.

River Flows

This section references the discussion presented in **Section TA 3.2.4**, Issue 4, as presented in **TA 3**, Hydrologic Conditions, with additional references to other sections as appropriate. The analysis focuses on Average Flow and Critically Dry Flow Categories. In all categories except the Critically Dry Flow Category, the high end of the results range has been cut off to improve comparisons in the average and drier flow conditions.

For the purposes of analyzing potential impacts related to changes in river flow, archaeological sites that may be physically affected are those located along or immediately adjacent to the river, where erosion caused by moving water may occur. As with the Lake Powell and Lake Mead datasets discussed above, variable survey coverage and older locational data must be taken into account. To identify the number of archaeological sites, built environment resources, and specially designated cultural resources that may be affected by changes in flow, sites with all or portions of their boundaries in the river corridor (bank to bank) or within 20 meters (66 feet) of the river corridor were identified from the

overall dataset using a GIS. For additional information on the cultural resources identified along the river by reach, please reference **Section TA 11.2.2,** Issue 1 in **TA 11**, Cultural Resources.

For all reaches, the impacts from changes in river flow would include water erosion from river currents during higher releases and flows but may also include exposure from lower water levels where either dam release or flow volumes are reduced; however, these impacts are only considered in this analysis when volumes fall outside the parameters of past releases or flows.

Glen Canyon Dam to Lake Mead

This section summarizes the potential for cultural resources to be affected by river flows below Glen Canyon Dam and references the median and interquartile WY release volumes (in maf) from the dam illustrated in **Figure TA 3-21** in **Section TA 3.2.3** and in **Table TA 3-14** at the end of **TA 3**, Hydrologic Resources. Since 2008 with the implementation of the 2007 Interim Guidelines, releases from Glen Canyon Dam have been in the range of around 7.0 maf to around 12.5 maf, averaging around 8.7 maf (see **Section TA 3.1.3**, Lake Powell and Glen Canyon Dam, in **TA 3**, Hydrologic Resources). In general, WY releases from Glen Canyon Dam that fall outside the historical range of around 7.0–12.5 maf have greater potential to impact known cultural resources within 20 meters (66 feet) of the river as well as on undiscovered resources that may be present along the river corridor. In addition, higher WY release volumes can increase erosion along the river corridor, even when releases remain in this historical range.

River flows from Lake Powell to Lake Mead primarily consist of controlled releases from Glen Canyon Dam. WY releases from the dam in the Average Flow Category would generally fall within the range of past annual release volumes as neither the CCS Comparative Baseline, No Action Alternative, nor the action alternatives (including the Representative Preferred Alternative) have median volumes that fall below 7.9 maf in the Average Flow Category. Therefore, there would be no additional impacts because none of the modeled scenarios would deviate from the established range. In the Average Flow Category, the interquartile range for the Enhanced Coordination Alternative would be the only modeled scenario that deviates from the range of past release volumes (7.0 maf up to 12.5 maf), as it is modeled to potentially drop to around 6.9 maf (25th percentile). Reductions in the volume of WY releases would affect river flows, thereby potentially exposing the Steamboat Charles Spenser. The same drops in river flows, resulting from reduced WY releases from Glen Canyon Dam, would not be detrimental to the one known historic property within 20 meters (66 feet) of the river because the boundary of the Lees Ferry and Lonely Dell Historic District extends into the river channel.

In the Critically Dry Flow Category, median WY release volumes for the CCS Comparative Baseline, No Action Alternative, and all action alternatives would fall below 7.0 maf, to as low as around 5.1 maf under the Enhanced Coordination Alternative. Under the critically dry hydrologic conditions, the No Action Alternative would perform better than the others relative to the upper limits of the interquartile ranges (75th percentile), which are around 7.7 maf for the CCS Comparative Baseline and around 8.2 maf for the No Action Alternative. The Representative Preferred Alternative has one of the narrowest interquartile range under critically dry hydrological conditions, with an upper limit around 6.0 maf, which is still below the bottom of the range of past flow volumes at 7.0 maf. All the modeled scenarios could impact the Steamboat Charles Spenser if the reduced volumes of these WY releases cause the river to drop below previous water levels. On the other hand, these same potential

drops in river water level would protect the only NRHP-listed property within 20 meters (66 feet) of the river (the Lees Ferry and Lonely Dell Historic District), as previously discussed.

Hoover Dam to Davis Dam

This section summarizes the potential for cultural resources to be affected by river flows below Hoover Dam to Davis Dam and refers to the median and interquartile CY release volumes from Hoover Dam as illustrated in **Figure TA 3-25** in **Section TA 3.2.3** and **Table TA 3-19** at the end of **TA 3**, Hydrologic Resources. Since 2008, CY releases from Hoover Dam have been in the range of around 8.5 maf to around 9.6 maf, averaging around 9.2 maf (see **Section TA 3.1.7**, Hoover Dam to Lake Mohave, in **TA 3**, Hydrologic Resources). In general, CY releases from Hoover Dam that fall outside the historical range of around 8.5 to around 9.6 maf have greater potential to impact known cultural resources within 20 meters (66 feet) of the river as well as on undiscovered resources that may be present along the river corridor. For the Average Flow Category, the No Action Alternative is the only modeled scenario under which median CY release volume would remain within the 8.5–9.6 maf range for previous release volumes below Hoover Dam in this reach at around 8.6 maf. The CCS Comparative Baseline falls just under previous release volumes at around 8.3 maf. The action alternatives would not perform as well, with the median CY releases for the Basic Coordination Alternative in the Average Flow Category around 8.0 maf, followed by the Representative Preferred Alternative at around 7.9 maf, the Maximum Operational Flexibility Alternative at around 7.8 maf, the Supply Driven Alternative (LB Priority and LB Pro Rata approaches) at around or just below 7.7 maf, and the Enhanced Coordination Alternative at just below 7.6 maf. Where impacts on archaeological sites result from erosion caused by moving water, these may be less likely to occur if the reduced CY release volumes cause the river to drop below previous water levels. The same drops in river water levels would not be detrimental to NRHP-listed Willow Beach Gaging Station.

For the Critically Dry Flow Category, median CY release volumes would be well below previous volume ranges under the CCS Comparative Baseline, No Action Alternative, and all action alternatives, which would fall below 8.0 maf, down to as low as around 6.4 maf for the Maximum Operational Flexibility Alternative, with the Enhanced Coordination Alternative slightly higher at around 6.5 maf. Again, relative to impacts on archaeological sites that may be subject to erosion caused by moving water, the ranges of all the modeled scenarios may be less likely to physically affect archaeological sites if the reduced CY release volumes cause the river to drop below previous water levels. Likewise, these same potential drops in river water level would not impact the NRHP-listed Willow Beach Gaging Station previously discussed.

Within this reach is Lake Mohave, which is operated under a rule curve that maintains end-of-month target elevations between 630 feet and around 646 feet and which has been kept relatively constant at around 641 feet since 2008 (see **Section TA 3.1.7**, Hoover Dam to Lake Mohave, in **TA 3**, Hydrologic Resources). There are no anticipated impacts on any known cultural resources around the reservoir in this portion of the reach, regardless of scenario, because Lake Mohave would continue to be operated under the existing rule curve.

Below Davis Dam

No impacts under the CCS Comparative Baseline, No Action Alternative, and all action alternatives are expected below Davis Dam. Davis and Parker Dams will continue to be operated under the current rule curves that determine end-of-month target elevations for Lake Havasu (see **Section TA**

3.1.8, Davis Dam to Lake Havasu, in **TA 3**, Hydrologic Resources). Imperial Dam is operated to maintain a nearly constant elevation to meet water delivery requirements for major diversions to California and Arizona (see **Section TA 3.1.10**, Cibola Gage to Imperial Dam, in **TA 3**). Additionally, the river below Imperial Dam is characterized by several stretches of mechanically channelized river corridor.

Issue 2: How will changes in dam operations affect sediment availability for aeolian transport to protect archaeological sites in the Grand Canyon?

This section references **Section TA 11.2.3**, Issue 2, in **TA 11**, Cultural Resources, as well as **Section TA 9.2.2**, Issue 1, in **TA 9**, Vegetation Including Special Status Species, and **Section TA 5.2.5**, Issue 4, in **TA 5**, Geomorphology and Sediment. As discussed in S**ection TA 11.2.1**, Methodology, in **TA 11**, the aeolian transport model looks at favorable conditions for wind-deposited sand to be present to protect archaeological sites over long periods of time using projected vegetation cover and exposed sand area or sandbar volume (Butterfield and Palmquist 2026; Kelley et al. 2026; Salter and Grams 2026). The vegetation and sandbar volume modeling used is from the Marble Canyon sub-reach from Lees Ferry to the Little Colorado River. The exposed sand modeling was conducted for the portion of the river from Lees Ferry to Bright Angel Creek. Although the analyses are limited to these reaches, the results provide general insight into sediment and vegetation responses that may also occur in other portions of the river corridor with similar geomorphic and hydrologic conditions.

Overall, less annual total vegetation cover is better for aeolian sand transport because it leaves available sand exposed to be picked up by the wind. As discussed in **Section TA 9.2.2**, Issue 1, and seen in **Figure TA 9-14** in **TA 9**, Vegetation Including Special Status Species, for all modeled scenarios in wet and moderately wet conditions there would be less annual total vegetation cover (below modeled historical conditions, indicated by the dashed line in **Figure TA 9-14**) from higher water levels and longer HFEs. As conditions grow drier, water flows diminish, and HFEs are shorter, annual total vegetation cover thereby increases (see **Figure TA 9-14** in **TA 9**). In dry and critically dry conditions, total annual vegetation cover increases and differentiation between alternatives can be seen. For the Critically Dry Flow Category, the medians and interquartile ranges are above the modeled historical conditions (dashed line) for all sub-reaches and all alternatives except the interquartile range for the CCS Comparative Baseline, which drops just below the dashed line (see **Figure TA 9-14** in **TA 9**). This indicates that there may be more annual total vegetation cover, especially under critically dry flows.

As discussed in **TA 5**, for an HFE to be triggered, enough sand needs to be available in Marble Canyon and enough water needs to be available in Lake Powell (as measured by water level), with both the required amounts of sand and water being dependent on the selected HFE duration. Additionally, HFE releases can only be implemented when Lake Powell water levels are at or above 3,500 feet, with sandbar deposition occurring most rapidly during the first 4 days of an HFE event. Lastly, sandbar volume modeling uses the assumption that HFEs are implemented as often as possible (see **Section TA 5.2.1**, Modeling Criteria and Assumptions). For the aeolian transport model, increased exposed sandbar volume means more sand is available to protect archaeological sites. In general, as conditions get drier and the amount of water flowing through the river decreases, exposed sandbar volume increases (see **Section TA 5.2.5**, Issue 4, in **TA 5**, Geomorphology and Sediment). Differences in performance among the alternatives also increase as hydrological conditions become drier, with the

Enhanced Coordination and Maximum Operational Flexibility Alternatives performing the best for the Critically Dry Flow Category (see **Figure TA 5-12** in **Section TA 5.2.5**).

The results of the WY average of exposed sand area modeling are seen in **Figure TA 11-4** (see **TA 11**, Cultural Resources), with the 90th percentile and median (50th percentile) of modeled sand areas depicted as two dashed lines. As with exposed sandbar volume, increased exposed sand area is beneficial for the aeolian transport of sand to protect archaeological sites. In the Average Flow Category, median exposed sand area is around the 90th percentile (upper dashed line) and the median (50th percentile, lower dashed line) of modeled sand area (in million square meters). As conditions become drier, all modeled scenarios perform similarly with modeled median exposed sand area above the observed median, with the No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives having slightly higher median values than the CCS Comparative Baseline and the other action alternatives, particularly in the Critically Dry Flow Category. Under critically dry conditions, the Maximum Operational Flexibility Alternative has the most variability with the greatest interquartile range.

The above three models are used in the aeolian sand modeling. **Figure TA 11-5** in **TA 11**, Cultural Resources, shows the results of the aeolian sand modeling, in which some futures meet one of two criteria: either the annual sand area is greater than the median observed sand area over the last 20 years and the vegetation cover area is less than median observed area over the last 20 years or the sandbar volume is greater than 1.5 times the initial condition. Based on previous studies and as shown in the table (in the highlighted row), those criteria being met at least 1 out of every 3 years is the optimal condition for enough sand to be available for aeolian transport.

Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would be the most robust at meeting the preferred minimum performance in 19 and 18 percent of futures, respectively, followed by the No Action Alternative only in 14 percent of futures. The Basic Coordination Alternative meets the preferred minimum of performance in only 9 percent of futures, with the Representative Preferred Alternative meeting it in only 6 percent of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the least robust, meeting the preferred minimum performance in only 3 percent of futures, with the CCS Comparative Baseline only slightly higher at 4 percent of futures. If the year interval is lengthened to 1 out of 4, 5, or 6 years, the models perform in a similar overall pattern, with the Enhanced Coordination Alternative performing the best until reaching 1-out-of-6-year interval when the No Action Alternative performs the best over the full modeling period.

If the modeling period is broken out for the first 10 years, the No Action Alternative performs the best, meeting the preferred minimum performance in 38 percent of futures for the highlighted interval, followed by the Enhanced Coordination Alternative at 35 percent of futures in the first decadal period (2027–2039), followed by the Maximum Operational Flexibility Alternative at 30 percent of futures. The Basic Coordination Alternative and the CCS Comparative Baseline meet the preferred minimum of performance in 18 percent and 19 percent of futures, respectively, followed by the Representative Preferred Alternative at 17 percent. The Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches) performs with only 9 percent of futures meeting the minimum preferred performance. Due to aeolian transport favoring drier conditions because more useable sand is available and the beginning of the first decadal period (2027-2039) is anticipated to have low

reservoir elevations, the modeling for this breakout (2027–2039) depicts more modeled futures meeting the preferred minimum of performance across the CCS Comparative Baseline, the No Action Alternative, and all action alternatives than over the full modeling period. Refer to **Figure TA 11-5** in **TA 11** (Cultural Resources) for robustness modeled for 2040–2049 and 2050–2060 relative to multi-model aeolian transport condition.

The overall results seem to indicate an increase in the percentage of futures over time, which may correlate to increased available sand over time; however, the perceived increase is driven by an increase in sandbar volume over time in the modeling with the understanding that HFEs would continue as planned. In reality, the decision to conduct HFEs depends on annual review and the actual HFE frequency may differ from that assumed or predicted in the modeling.

Summary Comparison of Alternatives

The Enhanced Coordination and Maximum Operational Flexibility Alternatives would perform better for Lake Powell in terms of maintaining water levels in drier conditions that would expose fewer archaeological sites and protect more through inundation. Because the continuous inundation of archaeological sites is more conducive to preservation than repeating cycles of inundation and exposure due to the risks of wave action, changes in lake elevations that may expose previously inundated resources to impacts such as wet-dry cycling and wave action are the biggest concern. As conditions become drier at Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would perform the best in the Average Flow Category with median water elevations from around 3,600 feet to around 3,630 feet. They also would perform best in the Critically Dry Flow Category; however, between 3,510 feet and 3,560 feet for these two action alternatives, potentially leaving (at minimum) between 316 and 381 archaeological sites and any undiscovered sites above these elevations exposed. The Enhanced Coordination Alternative is the most robust in terms of the preservation risk model, meeting the minimum preferred performance in 47 percent of futures, followed by the Maximum Operational Flexibility Alternative at 28 percent of futures over the full modeling period. This relational pattern is consistent if the full modeling period is broken out into shorter ranges, including the first decadal period (2027–2039) where the Enhanced Coordination Alternative also performs the best at 30 percent of futures, followed again by the Maximum Operational Flexibility Alternative at 25 percent of futures.

For Lake Mead, however, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would perform the best in the Average Flow Category, followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Projections indicate that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would have median elevations between 1,140 feet and 1,160 feet, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives would have median elevations between 1,100 feet and 1,130 feet, respectively, during average hydrological conditions. Recalling that lower reservoir levels means that more sites will be exposed, in the Critically Dry Flow Category, all scenarios would result in the exposure of at least 306 known archaeological sites (all but four in the Lake Mead dataset) as well as any undiscovered sites. However, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would have the potential to expose fewer sites with upper interquartile ranges up to around 1,030 feet. In addition, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would be the most robust for Lake Mead with respect to preservation risk, with 24 percent of the modeled futures

meeting the 2.24 threshold over the full modeling period, followed by the Maximum Operational Flexibility Alternative with 19 percent of futures. When examining the first decadal period (2027–2039) at Lake Mead, the percentage of futures meeting the preferred minimum of performance drops drastically. This is because the anticipated water levels for Lake Mead in 2027 are expected to be low and for this reason, robustness modeling shows a substantial drop in performance. For this first 10-year period, the Supply Driven Alternative (both LB Priority and LB Pro Rata) continues to perform the best, but only at 5 percent of futures, followed by the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative, and the Representative Preferred Alternative, all three of which meet the preferred level of performance in only 3 percent of futures.

Overall, for Lake Powell, the Enhanced Coordination and the Maximum Operational Flexibility Alternatives perform better in drier conditions and have the greatest potential to expose fewer known sites (therefore protecting more through inundation) while, for Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform better in drier conditions. The Representative Preferred Alternative falls in the middle for both lakes. The No Action and Basic Coordination Alternatives have the least potential to protect archaeological sites at both lakes.

Complicating these conclusions are modeling results for releases from both Glen Canyon Dam (WY releases) and Hoover Dam (CY releases), which show that, in the reaches between Glen Canyon Dam and Lake Mead and Hoover Dam to Lake Mohave, the median dam release volumes for both would drop lower under the Enhanced Coordination and Maximum Operational Flexibility Alternatives specifically in the Critically Dry Flow Category than compared to the CCS Comparative Baseline, the No Action Alternative, and the other action alternatives. Under all the modeled scenarios, the Steamboat Charles Spenser could be affected if the reduced volumes of the WY releases from Glen Canyon Dam cause the river to drop below previously observed water levels. On the other hand, these same potential drops in river water level may provide some protection from river currents for resources within 20 meters (66 feet) of the river.

Below Davis Dam, few to no impacts (regardless of flow category) are expected because the dams below Lake Mohave are operated under guidelines that maintain lake elevations or target water deliveries, and there are several stretches of channelized banks.

Relative to sediment availability for aeolian transport in the Grand Canyon, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would have the best outcome for increasing the availability of sand for wind transport to protect archaeological sites. Both alternatives have a similar percentage of futures meeting the preferred minimum of performance (in at least 1 out of every 3 years) at 19 and 18 percent, respectively. Although this seems to be a small percentage, these two action alternatives perform better than the CCS Comparative Baseline, the No Action Alternative, and the other action alternatives, all of which meet the preferred minimum of performance in 9 percent or fewer of futures.

3.12 Paleontological Resources

3.12.1 Affected Environment

Overview and Study Area

This section summarizes the paleontological resource environment of Lake Powell, Lake Mead, and the lower Colorado River corridor. The full detailed analysis of the paleontological resources' affected environment can be reviewed in **TA 12**, Paleontological Resources. Paleontological resources include any fossilized remains, traces, or imprints of organisms preserved in rock. The Paleontological Resources Preservation Act of 2009 (PRPA; 16 USC 470aaa–470aaa-11) and its implementation rule (43 CFR 49) require Department of the Interior agencies to preserve, manage, and protect paleontological resources on lands administered by Reclamation, the NPS, the BLM, and the FWS. The PRPA ensures these federally owned resources are available for current and future generations to enjoy and study as part of America's national heritage.

The study area for paleontological resources stretches from the northern extent of Lake Powell to the SIB in California via the Colorado River. It covers approximately 1 million acres across Utah, Arizona, Nevada, and California. This area includes known and unknown resources in Lake Powell and Lake Mead.

It is important to note that the resources within fluctuating water levels are vulnerable to wave action; those resources above water are at risk from visitation impacts. The PRPA requires federal protection, but the ongoing exposure of these resources highlights the need for more effective preservation efforts. The PRPA also requires Department agencies to develop plans for inventory and monitoring using scientific principles and expertise. These plans must emphasize interagency coordination and collaborative efforts, when possible.

Potential Fossil Yield Classification System

The study area was mapped using the BLM's Potential Fossil Yield Classification (PFYC) system. This system assigns ranks to geologic units based on the relative abundance of vertebrate or other fossils and the sensitivity of those fossils to adverse impacts. For more information on how the PFYC system was created and is regularly updated, please refer to **Section TA 12.1.1**, Study Area, in **TA 12**, Paleontological Resources. **Table 3-8**, below, depicts the acreages of PFYC ranks within the study area. Geologic units with a higher potential for containing paleontological resources are assigned a higher number. Approximately 27 percent of the mapped area is classified as high/very high potential (PFYC 4-5). Maps of the study area can be found in **Section TA 12.1.1** (**Map TA 12-1** through **Map TA 12-8**).

Table 3-8
Acres of PFYC Classes in the Study Area

PFYC Class	Total Acres
1 (very low)	70,500
2 (low)	154,600
3 (moderate)	103,600
4 (high)	179,300

PFYC Class	Total Acres
5 (very high)	24,200
U (unknown)	113,700
W (water)	373,100
Total acres	**1,019,000**

Source: Reclamation GIS 2025; NWS GIS 2023.
*PFYC data do not cover the entire study area, especially in the waterbodies and portions of the Colorado River.

Key Drivers and Trends

Fluctuating water levels in both Lake Powell and Lake Mead pose significant threats to paleontological resources, including fossils and trackways preserved in sedimentary rocks. In reservoirs, cycles of inundation and exposure weaken softer rocks, such as sandstone, making them more susceptible to erosion. As water levels recede, previously submerged fossils are exposed to environmental factors like wind, sun, and temperature changes, which accelerate degradation. While sediment deposition can temporarily protect some sites, the exposure of fossil-rich layers as water levels recede increases the likelihood of weathering, fragmentation, and disturbance from human activity.

Human activity further exacerbates these challenges because exposed fossil sites attract recreational use, leading to soil compaction, vegetation damage, and unauthorized fossil collection. Water-related impacts, such as flooding, controlled reservoir releases, and increased river erosion, also threaten fossil preservation by accelerating the removal of fossil-bearing sediments. While erosion can reveal new paleontological resources, it simultaneously increases the risk of their loss. The study area, characterized byon steep topography and high recreational use, faces elevated erosion rates, making the balance between discovery and preservation increasingly challenging.

Erosion is the primary agent that exposes paleontological resources on the surface to then await discovery and documentation. Lake Powell and Lake Mead are interconnected; adjustments of water releases at Lake Powell have a downstream effect on Lake Mead. The impacts on paleontological resources due to natural processes are the same at both reservoirs, but the intensity of impacts and the resources affected vary. Paleontological resources in Glen Canyon NRA are largely more understood and considered to be highly scientifically important. Most of the area is ranked PFYC 4 (high) or PFYC 5 (very high), including the shorelines (BLM GIS 2025). In Lake Mead NRA, the paleontological resources are less understood, and much of the shoreline is mapped as PFYC U (unknown; BLM GIS 2025). Therefore, the erosion concerns at Lake Powell are extremely high, as these conditions are affecting geologic units with high and very high paleontological value.

Reservoirs and Colorado River Corridor Overview

Lake Powell and Glen Canyon Dam

Lake Powell and Glen Canyon Dam make up most of Glen Canyon NRA, which spans southern Utah and northern Arizona and contains one of the most extensive sedimentary records on the Colorado Plateau. This record represents approximately 300 million years of geologic history and chronicles significant events, including the assembly and breakup of Pangea, the evolution of inland seas, and the incision of the Colorado River (Anderson et al. 2010).

Glen Canyon NRA staff is conducting a paleontological resources inventory survey; because of the size of the recreation area, the survey is being done in phases, with the latest phase completed in 2024. The three inventory reports provide the baseline data for a breadth of paleontological resources found within Glen Canyon NRA. Despite these efforts, natural processes such as erosion, mass wasting, and fluctuating water levels continue to expose and degrade fossil-bearing strata. Additionally, impacts from human intervention, such as vandalism, and unauthorized fossil collection, pose ongoing threats to resource preservation (Graham 2016; Santucci et al. 2009). In some areas, the buildup of sediment from dam operations may enhance fossil preservation by burial, while in others, it prevents discovery of those fossils. For more information about the paleontological resources in Glen Canyon NRA, please reference **Section TA 12.1.1**, Study Area.

Grand Canyon National Park

The Colorado River corridor of Grand Canyon National Park contains paleontological resources of exceptional scientific significance, spanning nearly 1.2 billion years of the earth's history. The river corridor is renowned for its dramatic display of geomorphic effects created by fluvial incision and its unique dry preservation of fossils from the Ice Age (Mead et al. 2020). The river channel serves as the physical axis along which the park's oldest and youngest fossil-bearing strata are exposed. The river channel is organized into two principal paleontological occurrences documented in the Grand Canyon National Park Centennial Paleontological Resource Inventory (Santucci and Tweet 2021): ancient body and trace fossils preserved within the canyon's deep bedrock formations, and Pleistocene and Holocene fossils recovered from dry caves and sediment deposits along the corridor walls.

The objective of the Grand Canyon National Park Centennial Paleontological Resource Inventory was to identify the scope, significance, distribution, and management issues associated with fossils in the park (Santucci and Tweet 2021). The river corridor presents particular management challenges due to its difficult terrain and limited accessibility, and the inventory acknowledges that systematic survey of inner canyon fossil localities remains incomplete. Despite this, the Colorado River corridor constitutes one of the most scientifically valuable zones within Grand Canyon National Park.

Lake Mead and Hoover Dam

Lake Mead NRA covers 1.5 million acres of southeastern Nevada and northwestern Arizona. Lake Mead NRA showcases a stratigraphic record spanning more than 500 million years of geologic history, documenting the evolution of the southwestern margin of North America. The NPS completed a comprehensive paleontological resource inventory in 2018. This inventory established baseline data for fossil-bearing formations and identified areas with high fossil potential; the inventory is confidential.

Resources at Lake Mead NRA are vulnerable to the same natural processes and human impacts described at Glen Canyon NRA. Continued monitoring and research are recommended to protect resources at Lake Mead NRA.

Lower Colorado River Corridor

Reclamation completed a paleontological resource inventory for the lower Colorado River region in 2020, which contained the river corridor as it extends from southern Nevada to the Mexico border (Bonde and Slaughter 2020). The corridor contains a sedimentary geologic record spanning 500 million years. Although not fully continuous, the corridor includes units representative of most geologic periods.

Under current conditions, water-related impacts such as erosion and recreation threaten the preservation of paleontological resources in the lower Colorado River corridor. Flooding events and controlled releases of reservoir waters can submerge fossils or increase river velocity and erosion, consequently displacing fossils from their geologic units. Water systems with steep cliffs and undercutting are also subject to higher rates of erosion and potential resource loss than flatter areas. Water-based recreational opportunities may unintentionally invite theft, vandalism, or indirect disturbance to fossils.

3.12.2 Environmental Consequences

Methodology

In this section, impacts on paleontological resources include those resulting from Reclamation's management of the water in Lake Powell and Lake Mead. Two types of analyses are used to evaluate impacts: preservation risk modeling, developed by the USGS and NPS, and aeolian transport-vegetative cover-HFE joint modeling, also developed by the USGS (Caster et al. 2026; Kelley et al. 2026). Additionally, PFYC data were used to analyze areas of high potential to contain fossils within the impact analysis area, and CRSS modeling of reservoir elevations was used to determine exposure risks.

The paleontological Preservation Hazard Model is informed by PFYC data and natural preservation hazards (slope erosivity, fetch distance, and water fluctuations) (Caster et al. 2026). To analyze this model using the DMDU framework, the model summarizes 10-foot elevation bins in Lake Powell and 5-foot elevation bins in Lake Mead so that each elevation from full pool to empty has a preservation risk rank. Next, projected monthly lake elevations are related to those elevation bins to estimate the preservation risk rank. As lake elevations drop, preservation risk generally increases. The model assumes that all resources have value, and dense resources and high erosion potential represent the highest risk; those with low erosion potential and no predicted resources represent the lowest risk.

Impact Analysis Area

The impact analysis area for paleontological resources consists of the Colorado River corridor from the upper limits of Lake Powell in Utah, through the Grand Canyon and Lake Mead in Arizona, and from Hoover Dam to the SIB.

Assumptions

The paleontological resource results are direct outputs from the Preservation Hazard Model and Joint Model. The impact analysis area includes known, unknown, and predicted resources and does not identify specific localities.

Impact Indicators

Four impact indicators were used to assess the impacts on paleontological resources due to operational activities: end-of-year lake elevations, changes in river flows, paleontological preservation risk rank, and the increase or decrease in sandbar building and the availability of windblown sediments to protect exposed resources.

Issue 1: How would fluctuations in water levels due to changes in dam operations (primarily in Lake Powell and Lake Mead) impact the exposure, erosion, and degradation of paleontological resources, including fossils and trackways?

For a detailed analysis of how the alternatives and CCS Comparative Baseline influence the preservation risk rank and impact the exposure, erosion, and degradation of paleontological resources, please reference **Section TA 12.2.2**, Issue 1.

This analysis references the modeling of paleontological preservation risk at the reservoirs. The model defines a historically derived threshold that is the 90th percentile risk rank from 2008 to 2024 LTEMP values. Exceeding this value means that a larger percentage of potential resources are exposed to erosion risks than what has happened since the reservoirs were filled. A higher number means a higher risk. The threshold at Lake Powell is a preservation risk rank of 2.93; the 2.93 threshold is a reference line based on past conditions (2008-2024) used to judge when risk is unusually high. The threshold at Lake Mead is 2.33.

Lake Powell

Reference **Table TA 12-4** and **Figures TA 12-4**, **12-5**, and **12-6** for the full modeling results of the preservation risk at Lake Powell. As shown in **Figure TA 12-4**, the Maximum Operational Flexibility Alternative and the Enhanced Coordination Alternative have similar ranges that are around or below the threshold in the Average Flow Category (12.0–14.0 maf). However, the Enhanced Coordination Alternative has a median risk value that is approximately 14 percent lower than what is modeled for the Maximum Operational Flexibility Alternative (2.45 and 2.85, respectively). In the Dry Flow Category (10.0–12.0 maf), the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative perform similarly well, although all alternatives exceed the historically derived threshold under the Critically Dry Flow Category (4.46–10.0 maf).

Focusing on trends in the drier hydrologic conditions, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs similarly to the CCS Comparative Baseline; the medians and ranges are above the threshold in the Dry and Critically Dry Flow Categories, although the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) exhibits slightly less variability. The No Action and Basic Coordination Alternatives also perform similarly, with medians higher than those of the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and CCS Comparative Baseline.

The Representative Preferred Alternative generally performs in the middle of the range of alternatives; it performs slightly better than the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) and slightly worse than the Maximum Operational Flexibility Alternative. At Lake Powell, the Representative Preferred Alternative does not perform notably for preserving paleontological resources.

When looking across the full modeling period (which includes the full range of potential hydrologic futures, or modeled hydrologic scenarios), the Enhanced Coordination Alternative performs significantly better than all other alternatives and the CCS Comparative Baseline, maintaining a preservation risk rank below the historically modeled threshold in 36 percent of futures. This is a difference of greater than 10 percent between the Enhanced Coordination Alternative and the closest performing alternative, the Maximum Operational Flexibility Alternative (successful in 22 percent of

futures). Based on the planned length of the decision, it is notable that the performance of all alternatives worsens between the full modeling period and the 2027-2039 subperiod, except for the Representative Preferred Alternative, which actually improves from 12 percent to 13 percent of futures in which the threshold is met.

These trends are supported by the vulnerability analysis (**Figure TA 12-6**), which looks at flow conditions that could cause the preservation risk rank to exceed the threshold. The Enhanced Coordination Alternative results in undesirable performance when the 10-year average flow is below 11.2 maf. Approximately 75 percent of the reference hydrology traces include averages this low or lower. As a historical reference, the driest observed 10-year average for the Lees Ferry flow was 11.8 maf and occurred from 2012 to 2021. The CCS Comparative Baseline and Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives performed the same, with paleontological resources becoming vulnerable at approximately 12.2 maf. For reference, the recently observed flow from 2016-2025 was 12.1 maf, meaning that these alternatives are vulnerable to conditions that have already occurred.

At Lake Powell, the Enhanced Coordination Alternative performs the best with respect to maintaining preservation risk ranks at or below the historically defined threshold, followed closely by the Maximum Operational Flexibility Alternative. The Representative Preferred Alternative generally performs in the middle of the alternatives, indicating that paleontological resources in Lake Powell would be subject to exposure, erosion, and degradation more frequently than what has been historically observed

Lake Mead

Reference **Table TA 12-4** and **Figures TA 12-7**, **12-8**, and **12-9** for the full modeling results of the preservation risk at Lake Mead. As shown in **Figure TA 12-7**, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Maximum Operational Flexibility Alternative perform almost identically in the Average Flow Category (12.0–14.0 maf), with similar median preservation risk ranks and an interquartile range at or below the 2008–2024 defined threshold. The Enhanced Coordination Alternative has a slightly greater median preservation risk, but it has a similar interquartile range to the other best-performing alternatives. The Representative Preferred Alternative performs similarly to the Enhanced Coordination Alternative, but it has greater variability and a larger proportion of its interquartile range above the historically defined threshold. Under all flow conditions, the No Action Alternative repeatedly exhibits the highest median and largest interquartile range, indicating that conditions would be unpredictable but more likely than not would result in greater risk to the preservation of paleontological resources.

Under the Dry and Critically Dry Flow categories, the Representative Preferred Alternative continues to perform similarly to the Enhanced Coordination Alternative, though it exhibits medians and interquartile ranges above the historically derived threshold. The Representative Preferred Alternative is outperformed by the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which maintains an interquartile range below the threshold in both the Dry and Critically Dry Flow categories.

When looking across the full modeling period, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) was the most robust at achieving a risk rank of 2.3 in 90 percent of months, doing so in 35 percent of futures. The other action alternatives range between robustness of 2 percent

of futures (No Action Alternative) and 16 percent of futures (Maximum Operational Flexibility Alternative). However, it is notable that no alternatives achieve robustness in the 2027-2039 subperiod, with performance dropping significantly (greater than 10 percent) for the Supply Driven (both LB Priority and LB Pro Rata approaches), Maximum Operational Flexibility, and Enhanced Coordination Alternatives. The Representative Preferred Alternative is successful in 3 percent of futures between 2027 and 2039, indicating that paleontological resources would certainly be exposed and subject to erosion and degradation in Lake Mead during this time.

These trends are supported by the vulnerability analysis (**Figure TA 12-9**). Paleontological resources are the most vulnerable to risk under the CCS Comparative Baseline and the No Action Alternative. Undesirable performance occurs at 12.5 maf; nearly 100 percent of the reference hydrologic traces include average flows of 12.5 maf or lower. These two scenarios are vulnerable to conditions that have already occurred; the 10-year average flow at Lees Ferry from 2016 to 2025 was 12.1 maf. The Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives are vulnerable to increased risk to paleontological sites at flows of 12.2 maf, indicating that these resources are vulnerable to conditions that have already occurred. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would be vulnerable at flows of 11.6 maf; nearly 75 percent of all hydrologic traces are drier 11.6 maf.

At Lake Mead, paleontological resources would be the least vulnerable to exposure, erosion, and degradation under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). The Representative Preferred Alternative performs similarly but would result in greater instances of exposure and erosion. Given the length of the planned decision, paleontological resources in Lake Mead would almost certainly be subject to drier conditions than what has been historically observed, resulting in greater risk to preservation.

Issue 2: How would altered sediment transport, including both fluvial and aeolian deposition patterns, affect the preservation and stability of paleontological resources?

The preservation and stability of paleontological resources along the Colorado River corridor are closely tied to sediment dynamics, particularly the deposition and redistribution of fine sediments through fluvial and aeolian processes. Sediment burial helps protect surface-exposed resources from erosion, weathering, and human disturbance, while changes in the magnitude or timing of sediment delivery may either enhance or degrade preservation conditions. However, increased exposure of sandbars and sediment surfaces typically heightens the risk of erosion, weathering, and loss of fossil integrity, while sediment deposition and rapid burial may provide temporary protection from degradation. Frequent water level fluctuations that alternately expose and inundate sediments are generally detrimental to long-term preservation.

Fluvial Sediment Transport

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to the fraction of total sand mass transported by sandbar-forming flows. For more information, please reference **TA 5**, Geomorphology and Sediment.

As shown in **Figure TA 12-10** in **TA 12**, Paleontological Resources, the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform similarly, achieving sandbar-building conditions in 83 and 85 percent of futures, respectively. The Supply Driven (both LB Priority and LB Pro Rata

approaches) and Representative Preferred Alternatives are similarly robust (78 percent and 76 percent of futures, respectively). Sandbar-building conditions indirectly result in the preservation and stabilization of paleontological resources present in and around the sandbars. Fossils may be buried during sediment transport and protected from erosion and other types of degradation in the fluvial channel. It is likely that paleontological resources would be buried by fluvial sediment transport at a significant frequency under the Representative Preferred Alternative, resulting in better conditions for preservation.

In contrast, the No Action Alternative was successful in only 44 percent of futures; the CCS Comparative Baseline produced 36 percent of successful futures. Under the No Action Alternative, fossils and other paleontological resources would be indirectly affected by sandbar erosion between HFEs and not effectively reburied during sandbar-building events.

Aeolian Sediment Transport

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to favorable conditions for windblown sand to be present to protect paleontological resources over long periods of time. The model incorporates the vegetation, sandbar volume, and exposed sand area modeling. For more details, please reference **Section TA 12.2.1**, Methodology.

Figure TA 12-12 in **TA 12**, Paleontological Resources, shows the results of the aeolian sand modeling, in which the percentage of futures meet one of two criteria: Either the annual sand volume is greater than the median observed sand volume over the last 20 years and the vegetation cover area is less than the median observed area over the last 20 years, or the sandbar volume is greater than 1.5 times the initial condition. The highlighted row shows when those conditions are met at least 1 out of every 3 years, which is the optimal time frame for enough sand to be available for aeolian transport based on previous studies.

Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust; they meet the desired conditions of at least 1 out of every 3 years in 19 percent and 18 percent of futures, respectively. The No Action Alternative meets the desired conditions in 14 percent of futures, and the Representative Preferred Alternative meets the desired conditions in only 6 percent of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the least robust, meeting the desired conditions in only 2 percent of futures. If the year interval is lengthened (that is, to 1 out of 4, 5, or 6 years), the models perform in a similar overall pattern, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives performing the best.

When results are split out over intervals from 2027–2039, 2040–2049, and 2050–2060, the percentage of futures meeting the desired conditions increases for all alternatives. The robustness of the Representative Preferred Alternative increases from 6 percent of futures to 17 percent between 2027 and 2039. These results seem to indicate an increase in acceptability over time, which may correlate to increased available sand over time; however, the perceived increase is driven by an increase in sandbar volume over time in the modeling with the understanding that HFEs would continue as planned. In reality, the decision to conduct HFEs depends on the annual review.

It is notable that the Representative Preferred Alternative meets the desired conditions in 17 percent of futures between 2027 and 2039, indicating that the conditions required for aeolian transport will not occur frequently, exposing paleontological resources to erosion and other weathering mechanisms.

Issue 3: How would adjustments to dam operations and water levels alter human access to newly exposed fossil sites, and what are the potential risks of increased disturbance, unauthorized collection, and recreational impacts on paleontological resources?

This section summarizes the potential for paleontological resources to be exposed to increased levels of disturbance, unauthorized collection, and recreational impacts using the hydrologic modeling results for Lake Powell and Lake Mead elevations. This analysis incorporates the analysis of reservoir elevations detailed in **Section TA 3.2.1**, Issue 1: Reservoir Elevations, in **TA 3**, Hydrologic Resources**.** For a detailed analysis of how the alternatives and CCS Comparative Baseline influence the risk of human disturbance to paleontological resources, please reference **Section TA 12.2.4**, Issue 3.

Lake Powell

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to increased disturbance at, unauthorized collection of, and recreational impacts on paleontological resources at Lake Powell. For a more detailed analysis of recreation at Lake Powell, please refer to **TA 14**, Recreation.

As shown in **Figure TA 3-7** in **TA 3**, Hydrologic Resources, the alternatives perform similarly with respect to maintaining lake elevations and achieving desirable paleontological preservation risk ranks. The Maximum Operational Flexibility Alternative and the Enhanced Coordination Alternative are the most robust at staying above a 3,500-foot elevation in 100 percent of months over the full modeling period, doing so in 86 percent and 74 percent of futures, respectively. These results are similar to the robustness of both alternatives with regard to achieving the historically derived preservation risk threshold in 90 percent of months.

The No Action Alternative is the least robust at maintaining a 3,500-foot elevation in 100 percent of months, doing so in 20 percent of futures over the full modeling period. The No Action Alternative is only 71–80 percent robust at maintaining this elevation in 60 percent of months. The CCS Comparative Baseline, Basic Coordination Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform similarly, maintaining the 3,500-foot elevation in 100 percent of months in 29 percent, 25 percent, and 24 percent of futures, respectively.

The Representative Preferred Alternative meets this robustness criteria in 28 percent of modeled futures in the full modeling period. Based on the planned length of this alternative, it is important to note that it meets the preferred minimum performance level in 49 percent of futures between 2027 and 2039. Alternatives that keep Lake Powell at or above 3,500 feet more often will keep most sites below that level underwater (and protected) more of the time. Therefore, the risk of human disturbance would be for resources above 3,500 feet. The preservation risk rank historically derived threshold is achieved at approximately 3,500-foot elevation at Lake Powell. Under the Maximum Operational Flexibility Alternative, elevations at Lake Powell would be most consistently at or above 3,500 feet, which would result in the inundation of the most paleontological resources and the least amount of shoreline expansion for visitors to access resources.

Lake Mead

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to increased disturbance at, unauthorized collection of, and recreational impacts on paleontological resources at Lake Mead.

As shown in **Figure TA 3-12** in **TA 3**, Hydrologic Resources, the alternatives perform similarly with respect to maintaining lake elevations and achieving desirable paleontological preservation risk ranks. The Supply Driven Alternative (LB Pro Rata approach) and Maximum Operational Flexibility Alternative are similarly robust at keeping Lake Mead's elevation above 975 feet in 100 percent of months, doing so in 73 percent and 70 percent of futures, respectively. The Enhanced Coordination Alternative and the Supply Driven Alternative (LB Priority approach) are also similarly robust, maintaining Lake Mead's elevation above 975 feet in 65 percent and 61 percent of futures, respectively.

The Representative Preferred Alternative meets this robustness criteria in 50 percent of modeled futures in the full modeling period. Based on the planned length of this alternative it is important to note that it meets the preferred minimum performance level in 66 percent of futures between 2027 and 2039.

The No Action Alternative is the least robust, keeping Lake Mead elevation above 975 feet in 100 percent of months in 21 percent of futures over the full modeling period. Robustness of the CCS Comparative Baseline is 38 percent; robustness of the Basic Coordination Alternative is 50 percent.

Summary Comparison of Alternatives

Continuous inundation preserves paleontological resources better than repeated exposure to waves and wet-dry cycles. Changes in lake elevations that may expose previously inundated fossils and other resources are the biggest concern. When lake elevations drop, indirect impacts, such as those from human disturbance and recreational use, can also occur. For Lake Powell, the Enhanced Coordination Alternative performs best with regard to minimizing the preservation risk in all hydrologic conditions, except the Critically Dry Flow Category (4.46–10.0 maf), followed by the Maximum Operational Flexibility Alternative. Both alternatives exhibit median risk ranks that are at or below the threshold.

The Basic Coordination Alternative is the least effective action alternative with regard to meeting the paleontological preservation risk threshold at Lake Powell. This alternative becomes successful at the Moderately Wet Flow Category (14.0–16.0 maf), but it consistently exceeds the threshold at the Average Flow Category (12.0–14.0 maf) and drier. The No Action Alternative and CCS Comparative Baseline perform similarly to the Basic Coordination Alternative.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Maximum Operational Flexibility Alternative perform similarly and produce a median preservation risk rank around, or just above, the historically derived threshold in all hydrologic conditions except for the Critically Dry Flow Category (4.46–10.0 maf). All alternatives exceed the historical preservation risk conditions under the Critically Dry Flow Category (4.46–10.0 maf).

Under the Maximum Operational Flexibility Alternative, critical lake elevations would be maintained above 3,500 feet in Lake Powell and 975 feet in Lake Mead in 86 percent and 70 percent of futures, respectively. The operations proposed under the Maximum Operational Flexibility Alternative would

result in the least amount of time that paleontological resources below critical elevations are exposed to human disturbance and the associated impacts. The No Action Alternative would be the least robust at both reservoirs.

Under the Maximum Operational Flexibility Alternative, the paleontological preservation risk would be minimized to the greatest extent at both reservoirs. Paleontological resources that remain inundated would not be exposed to erosion, degradation, and the repeated cycles of inundation and exposure and wave action. The Enhanced Coordination Alternative would also minimize the paleontological preservation risk in the reservoirs, but it would do so more consistently at Lake Powell than at Lake Mead. Considering the amount of, and scientific importance of, paleontological resources present in Lake Powell, the Enhanced Coordination Alternative would be the most effective at minimizing the risk in this reservoir. The Enhanced Coordination Alternative would also be effective in Lake Mead, but not as effective as the Maximum Operational Flexibility Alternative.

The river corridor, from below Hoover Dam to the SIB, is not well mapped by the PFYC system. Classifications in the corridor are mostly PFYC W (water). While possible, the presence or impacts on scientifically important vertebrate fossils are not anticipated within the river corridor when compared with the potential for known or undiscovered fossils in the reservoirs. The Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative are the most robust alternatives with regard to sediment transport in the river corridor. Sediment transport would indirectly preserve and stabilize the known and unknown fossil localities.

Operations under the Maximum Operational Flexibility Alternative would indirectly create conditions that are most conducive to the preservation of paleontological resources in the analysis area, as indicated by this alternative's comparatively strong performance across the full suite of models.

For both Lake Powell and Lake Mead, the Representative Preferred Alternative generally performs somewhere in the middle of the action alternatives, never outperforming all alternatives in terms of paleontological resource risk reduction, fluvial and aeolian sediment transport, or maintaining significant lake elevations. Given the length of the planned decision, it is notable that paleontological preservation risk will likely be heightened under the Representative Preferred Alternative, as more resources will become exposed and eroded due to fluctuating reservoir levels and flows.

3.13 Tribal Resources

3.13.1 Affected Environment

The Colorado River, its canyons, and the associated ecosystems figure prominently in the cultural traditions of many tribal communities. For these tribes, the river and canyons are living entities consisting of sacred spaces, the homes of their ancestors, the residence of the spirits of their dead, and the source of culturally important resources. Indigenous worldviews do not separate cultural and natural environments as Western science often does; instead, they view all resources—whether considered cultural or natural in Western frameworks—as interconnected and interdependent. Many tribes see themselves as stewards of the Colorado River and its canyons, which are a vital part of the living and spiritual world. Caring for the river and the canyons is their responsibility. Tribal resources can include archaeological resources, archaeological structures, topographic features, habitats, plants,

wildlife, and minerals that Indigenous peoples, tribal nations, or other groups consider essential for the preservation of traditional culture and traditional values. For many tribes, the trails used to access the river are also considered culturally important landscape features. Tribal interests also include values and resources reflected in other sections in this Final EIS, including water for drinking and agriculture, recreational resources, and many other socioeconomic and environmental aspects that overlap other sections.

The traditional values of living communities can be manifested at locations called TCPs, Indian sacred sites, or cultural landscapes. Many tribes consider the Colorado River and its canyons to be a TCP. As described by NPS guidance on TCPs (NPS 2024b), a TCP is "a building, structure, object, site, or district that may be listed or eligible for listing in the National Register for its significance to a living community because of its association with cultural beliefs, customs, or practices that are rooted in the community's history and that are important in maintaining the community's cultural identity." Of the groups concerned, the Hualapai Tribe (Coulam 2011), Hopi Tribe (Hopi CPO 2001), Navajo Nation (Maldonado 2011), and Pueblo of Zuni (Dongoske 2011) have prepared NRHP nomination forms for the Colorado River and its canyons as a TCP. Reclamation is actively consulting with the tribes regarding the Colorado River and its canyons, including associated traditional ecological knowledge; Reclamation will incorporate that knowledge as it becomes available.

The study area for tribal resources is identical to that discussed in **TA 11**, Cultural Resources, and **TA 18**, Indian Trust Assets. It extends from the northern extent of Lake Powell to the SIB and consists of the Colorado River channel from bank to bank, except from Glen Canyon Dam to Lake Mead, where it stretches from canyon rim to canyon rim. The study area also includes a 0.5-mile buffer on either side of the riverbank or canyon rim. The study area coincides with the search area used for a Class I records search conducted for this EIS document (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi 2024).

The 14 Native American tribes listed here consider portions of the study area to be part of their homelands; the following eight tribes are associated directly with the Grand Canyon: A:shiwi (Zuni), Ndee (Western Apache), Diné (Navajo), Havasupai, Hualapai, Hopi, Nüümü (Southern Paiute), and Yavapai. Five tribes—the Cocopah, Pipa Aha Macav (Mojave), Piipaash (Maricopa), Quechan, and Xalchidom (Halchidhoma)—have homelands along the lower Colorado River where it flows south to the Gulf of California. One group, the Núuchi (Ute), used northeastern portions of the river and study area. Contemporary Native American communities face a host of common issues such as widespread poverty, health disparities, and housing shortages. For the Native American tribes discussed here, water shortages and the potential to impact agriculture is a significant concern. Brief ethnographic summaries of these tribes are provided in **Sections TA 13.1.1** through **TA 13.1.13**. These summaries focus on indigenous cultural connections to the Colorado River landscape and are derived primarily from the multivolume Class I cultural resources literature review conducted in support of this analysis (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi et al. 2024).

Several known or documented TCPs within or adjacent to the study area have been listed or are eligible for listing in the NRHP (**Table TA 13-1**). For example, Sugarloaf Mountain to the west of the lower Colorado River is identified as a TCP by the A:shiwi, Diné, Hopi, Hualapai, Nuwuvi, Pipa Aha Macav, and Yavapai. The Ripley Intaglios are considered sacred by all the Yuman Tribes. The Yuman Tribes consider their origin place, Avi Kwa Ame (Spirit Mountain), to be sacred; it is beyond the

project study area but within the newly created Avi Kwa Ame National Monument. Through ongoing consultation with tribes, the locations of several additional places that are considered sacred have been disclosed to Reclamation cultural resources staff. At the request of these tribes, descriptions and locations of those sacred places are confidential. Tribes discussed in this section revere the Colorado River. The Grand Canyon itself is an NRHP-eligible TCP for multiple tribes. Several important locations within the Grand Canyon TCP have been formally recorded in the canyon for the A:shiwi and Hopi and documented in ethnographic studies for the Diné and Hualapai.

Tribes consider places associated with origin stories, migrations, songs, and ceremonies to be sacred TCPs, as are ancestral sites, trails, cairns, rock writing, petroglyphs, pictographs, and geoglyphs. All water sources, especially those that come from belowground, are sacred. Plants, animals, and minerals are considered traditional cultural resources, often associated with specific locations. Reclamation is in ongoing consultation with tribes to identify specific locations and resources that are important to each tribe.

3.13.2 Environmental Consequences

Methodology

Of primary concern is how the alternatives might affect the integrity and sacredness of tribal resources. Because these resources attain significance through tribal cultural customs, and because many of these resources are sacred and their locations are confidential, the tribes are best situated to understand how the alternatives might affect them. Accordingly, the impact analysis is primarily qualitative and informed by ongoing tribal consultation.

There are many federally recognized tribes with entitlements to or contracts for Colorado River water or who may be affected or have interests in the alternatives. There are 30 federally recognized tribes within the geographic Basin. Reclamation consults regularly with these tribes regarding Colorado River issues. Additionally, the Ten Tribes Partnership is a coalition of 10 federally recognized tribes with rights and unresolved claims to Colorado River water. The partnership was created in 1992 and has an ongoing consultation relationship with Reclamation. Of the 22 federally recognized tribes in Arizona, 4 have quantified water rights, or partially quantified rights to water from the mainstream Colorado River through the Consolidated Decree. Another 10 tribes in Arizona have entered water rights settlements that include Central Arizona Project (CAP) water, one source of which is Priority 4 Arizona Colorado River water. Several more tribes hold CAP contracts. Reclamation consults not only with tribes who hold water rights or are located within the Basin's geographic boundary but also with a total of 43 tribes who may be affected or have interests in actions on the Colorado River. Consultation and coordination with these tribes are ongoing.

Impact Analysis Area

The study area for tribal resources is identical to that discussed in **TA 11**, Cultural Resources. It includes the Colorado River corridor from the upper limits of Lake Powell in Utah, through the Grand Canyon in Arizona and Lake Mead in Arizona, and from Hoover Dam to the SIB.

Assumptions

- Tribes will provide information regarding specific tribal resources and potential impacts on those resources during consultation.

Impact Indicators

- Qualitative assessment of potential impacts on TCPs informed by tribal consultation
- Qualitative assessment of potential impacts on culturally important resources informed by tribal consultation and by reference to relevant quantitative analysis sections of the EIS (for example, **TA 9**, Vegetation, and **TA 8**, Biological Resources – Fish and Aquatic Resources)

Issue 1: How would changes in dam operations affect TCPs?

TCPs are historic properties that are principally significant for their association with culturally significant events, as told through Indigenous oral history, or their association with individuals named by those traditions. Impacts on TCPs would consist primarily of changes to the natural environmental context resulting from continued active management of reservoir levels and water releases to downstream river segments. Impacts could also occur as reservoir elevations change and expose TCPs to increased erosion or visitation. Because TCPs are a specific category of historic property, adverse impacts on TCPs would be addressed through the project's programmatic agreement developed in compliance with Section 106 of the NHPA or through ongoing consultation with affected tribes.

Exposure of TCPs as lake levels fluctuate as a result of management actions described by the alternatives could facilitate access to these culturally important locations by tribal members; however, exposure would also increase access for non-Native visitation. End-of-year lake elevations for each alternative are explored in detail in **TA 3**, Hydrologic Resources, and are summarized here in the discussion of impacts on TCPs.

Across all alternatives and the CCS Comparative Baseline, Lake Powell's median WY elevations are generally similar under wet hydrologic conditions, except for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which shows lower median elevations. As conditions become drier, Lake Powell's elevations decrease and the differences among alternatives become more pronounced, with operations varying widely at lower water levels.

In the two driest flow categories, the Enhanced Coordination Alternative maintains the highest median reservoir elevations, followed by the Maximum Operational Flexibility Alternative. Both alternatives keep median reservoir elevations well above the critical threshold of 3,500 feet, even during dry periods; therefore, they would expose the fewest number of TCPs to increased erosion or visitation. In contrast, the No Action Alternative and the Basic Coordination Alternative have median elevations that fall below this critical threshold in dry hydrologic conditions, and these alternatives would facilitate the greatest access to TCPs and potentially expose them to wave erosion. Under the Representative Preferred Alternative, Lake Powell elevations remain relatively stable compared to other alternatives. In both the Dry Flow and Critically Dry Flow categories the Representative Preferred Alternative maintains median elevation above 3,500 feet. The Critically Dry Flow category shows greater variability in median elevations.

For Lake Mead, median EOCY elevations also decline as conditions become drier, but the relative performance of each alternative remains consistent. The Supply Driven Alternative (LB Pro Rata approach) consistently has the highest median reservoir elevations across all flow categories, followed by the Supply Driven Alternative (LB Priority approach); therefore, these would expose the fewest number of TCPs to increased erosion or visitation. The No Action Alternative consistently has the lowest median elevations, with the CCS Comparative Baseline having the second lowest; these

alternatives would facilitate the greatest access to TCPs and subsequent erosion. Most action alternatives show wide variability in Lake Mead's elevations, except for the Maximum Operational Flexibility Alternative, under which the elevation reliably remains above 975 feet. Under the Representative Preferred Alternative, Lake Mead elevations show moderate variability in dry conditions and somewhat lower variability in critically dry conditions staying above 975 feet in most years.

Issue 2: How would changes in dam operations affect lake elevations (primarily in Lake Powell and Lake Mead) and river flows downstream, which could impact sacred sites?

Sacred sites are specific locations that a tribe has identified as sacred because of the sites' traditional religious significance or because the sites are a discrete location for ceremonial use. Sacred sites often overlap significantly with TCPs and with Indigenous archaeological sites. Accordingly, impacts on sacred sites are qualitatively similar to impacts on archaeological sites. Of primary concern are direct impacts like wave action and wet-dry cycling that could occur from changes in lake levels or from changes to river flows caused by annual releases. Impacts on archaeological sites are analyzed in detail in **TA 11**, Cultural Resources, and that discussion is summarized here.

At Lake Powell and Lake Mead, continuous inundation of sacred sites or Indigenous archaeological sites helps preserve them better than cycles of flooding and exposure, which increase risks from wave action. The main concern is that dropping lake elevations could expose such sites that were previously underwater, making them vulnerable to wet-dry cycles and wave impacts. As water levels fall, more sites become exposed to these risks at lower elevations. Sites at higher elevations may be less affected by wet-dry cycling and wave action but could become more accessible, depending on their location.

Hydrologic models show that during wet hydrologic conditions, Lake Powell's water levels are projected to remain above 3,660 feet in all scenarios. As conditions get drier, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain the highest median water levels during the Average Flow Category (12.0-14.0 maf), staying at or above 3,620 feet. These alternatives also perform best in the Critically Dry Flow Category (4.46-10.0 maf), but projected medians are still below 3,580 feet; this means sacred sites or archaeological sites—and any unknown sites—at these elevations would be exposed.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the highest water levels during both the Average and Critically Dry Flow Categories, followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has projected median elevations up to 1,150 feet in the Average Flow Category, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives have medians around 1,100 feet. In the Critically Dry Flow Category, all scenarios would expose sacred sites or archaeological sites and any unknown sites; however, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) could protect more sites, with upper interquartile ranges reaching about 1,120 feet. Under the Representative Preferred Alternative, Lake Powell and Lake Mead elevations are comparable to other alternatives though Lake Mead elevations show greater variability across alternatives for the driest flow categories.

This pattern is reflected in the Preservation Risk Model analysis. For Glen Canyon, the Enhanced Coordination Alternative is the most robust, and will impact the fewest sites, with 30 percent of

modeled futures in the initial modeling period staying below the preservation threshold, followed by the Maximum Operational Flexibility Alternative at 25 percent. Under the Representative Preferred Alternative the preservation threshold is met in 16 percent of modeled futures. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust during the initial modeling period, with 5 percent of modeled futures meeting or staying below the threshold. The Maximum Flexibility Alternative and Representative Preferred Alternative both stay below the preservation threshold in 3 percent of modeled futures.

For the Colorado River stretches between Glen Canyon Dam and Lake Mead, and between Hoover Dam and Lake Mohave, water release volumes in the Wet (16.0-31.11 maf) and Average Flow Categories generally remain within the range of past annual releases. However, in the Critically Dry Flow Category, median annual release volumes drop below 7.0 maf below Glen Canyon Dam, with the Enhanced Coordination Alternative reaching as low as 5.1 maf. Below Hoover Dam, the median annual flows fall below 8.0 maf, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives dropping to 6.5 maf. As a result, in critically dry hydrologic conditions, lower water levels increase the likelihood of sacred sites or archaeological sites near the riverbanks being exposed. The Representative Preferred Alternative has one of the narrowest interquartile range under critically dry hydrological conditions, with an upper limit around 6.0 maf, which is still below the bottom of the range of past flow volumes at 7.0 maf.

Below Davis Dam, impacts are expected to be minimal or nonexistent in any flow category. This is because the dams below Lake Mohave are managed to maintain lake elevations or meet targeted water deliveries, and many sections have channelized banks that further reduce exposure risks.

Issue 3: How would changes in dam operations impact natural resources important to Native Americans, including riparian vegetation and wildlife?

Indigenous worldviews do not differentiate between cultural and natural environments, as they do in Western science. Under many Indigenous perspectives, resources considered separately as cultural or natural are all interconnected and interdependent (Berkes 2018). Human interventions that disrupt these interconnections are considered adverse impacts. This EIS discusses many of these resources, such as water quality, air quality, terrestrial wildlife, and others. Although all resources are considered interconnected, Indigenous oral histories and ongoing consultation with Native American groups have identified riparian vegetation communities and aquatic wildlife as resource categories of particular concern along the Colorado River corridor. Accordingly, Reclamation considers riparian vegetation and aquatic wildlife (native and nonnative fish) below. Adverse impacts on these resources important to Native Americans would be addressed through ongoing consultation with the affected tribes.

TA 9, Vegetation, presents in detail the quantitative impacts on riparian vegetation communities and evaluations of which alternatives best support historical vegetation community conditions. Historical vegetation communities are those that prevailed in the decades prior to reservoir inundation and from Indigenous worldviews are the preferred condition. Those quantitative analyses are summarized here. Woody riparian vegetation is moderately tolerant of water fluctuations, but if variability increases over a 5-year period, these areas tend to decrease. Conversely, if water level variability decreases annually or over 5 years, woody riparian vegetation may expand.

For Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would maintain woody riparian vegetation most similar to historical conditions. For Lake Mead, the Maximum Operational Flexibility Alternative would best match historical vegetation patterns. However, in the stretch from Hoover Dam to the SIB, these two alternatives would cause vegetation to differ most from historical conditions, leading to greater changes in that area. The Basic Coordination Alternative would be least similar to historical conditions for Lake Powell but would be closest to historical vegetation patterns for Lake Mead and the Hoover Dam to SIB reach. The Representative Preferred Alternative would be least similar to historic conditions for Lake Powell and Lake Mead. This means no single alternative matches the historical vegetation conditions across all areas.

Most alternatives provide variability closer to historical conditions than the CCS Comparative Baseline in most reaches, except for Hoover Dam to the SIB, where only the Basic Coordination Alternative does so. This suggests that changing current management strategies would benefit much of the analysis area.

For the stretch between Glen Canyon Dam and Lake Mead, the alternative that best maintains historical vegetation depends on whether the starting hydrologic conditions are wet or dry. Under dry and critically dry hydrologic conditions, differences between the alternatives become more noticeable, especially in the lowest, median, and peak flows. However, across all alternatives, sub-reaches, and evaluation criteria (habitat area, native species richness, proportion of native species cover, and total annual vegetation cover), the interquartile ranges often overlap, making it hard to identify a clear best or worst alternative for preserving historical vegetation conditions.

Under all alternatives for Lake Powell, Lake Mead, and Hoover Dam to the SIB, the first decade is expected to have greater variability and reduced woody riparian habitats, compared with historical conditions. Conditions improve in the second and third decades, allowing vegetation to recover and be reestablished. If variability prevents woody riparian habitats from forming, the area may shift to another habitat type.

Quantitative impacts on aquatic wildlife are considered in detail in **TA 8**, Biological Resources – Fish and Other Aquatic Species, and those quantitative analyses are summarized here. Decreased water levels at Lake Powell affect lake and river habitats for culturally important native and nonnative fish. Among the alternatives, the No Action Alternative stands out because it increases the amount of exposed river habitat for endangered Colorado pikeminnow and razorback sucker, which is beneficial for these species. However, this also means less lake habitat for sportfish, which could negatively affect recreational fishing.

All alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives keep Lake Powell below critical elevation thresholds (3,598 feet for the Colorado River and 3,600 feet for the San Juan River), thereby increasing river habitat. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are less effective in this regard, as they tend to flood critical habitats and reduce the value of riverine habitat.

No alternative is particularly successful at maintaining Piute Farms Waterfall as a barrier to prevent nonnative fish from moving upstream. On the other hand, all alternatives support native fish passage over the waterfall when it is inundated. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the CCS Comparative Baseline are the most effective at maintaining the waterfall

as a barrier, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives are more likely to allow inundation and fish passage.

For Lake Powell, the Representative Preferred Alternative provides moderate protection of riverine critical habitat but does not perform as well as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). Overall, it represents a moderate balance but is less robust than the best-performing alternatives for specific indicators.

For Lake Mead, the alternatives would affect tributary inflow habitats of culturally important fish populations. The No Action Alternative and CCS Comparative Baseline are the most effective at keeping Lake Mead below 1,090 feet for at least 90 percent of months. This helps restrict nonnative fish and maintain the current species composition in the Grand Canyon. However, these lower elevations also hinder native species—such as razorback sucker, flannelmouth sucker, and humpback chub—from moving upstream into Grand Canyon habitats.

The Basic Coordination Alternative performs moderately well in balancing these outcomes. In contrast, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are less effective, as they more often allow Lake Mead to rise above critical thresholds. This can make it easier for both native and nonnative fish to move upstream.

Among the alternatives, the Supply Driven Alternative (LB Pro Rata approach) is the most reliable for keeping Lake Mead above its historical minimum elevation, which supports greater habitat stability.

Summary Comparison of Alternatives

TCPs are historic properties significant to Indigenous communities, mainly due to their association with culturally important events or individuals, as described in oral traditions. The main impacts on TCPs come from changes in the natural environment caused by managing reservoir levels and water releases, as well as increased exposure, erosion, and visitation where water levels drop. Adverse impacts on TCPs are addressed through a programmatic agreement and ongoing consultation with tribes, in compliance with the National Historic Preservation Act.

As lake levels fluctuate, TCPs may become more accessible to both tribal members and non-Native visitors. Under wet hydrologic conditions, most alternatives keep Lake Powell's water levels high and exposure of TCPs low, except for the Supply Driven Alternative, which has lower elevations. In dry hydrologic conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain the highest water levels, limiting TCP exposure, while the No Action and Basic Coordination Alternatives result in lower elevations and greater access to TCPs. For Lake Mead, water levels also drop as conditions get drier. The Supply Driven Alternative (LB Pro Rata approach) keeps the highest water levels and limits TCP exposure, while the No Action Alternative and CCS Comparative Baseline have the lowest levels, increasing access to TCPs. Under the Representative Preferred Alternative, Lake Powell and Lake Mead elevations remain relatively stable compared to other alternatives with increasing variability in the driest flow categories.

Sacred sites are locations identified by tribes for their religious or ceremonial significance; these sites often overlap TCPs and Indigenous archaeological sites. Impacts on sacred sites are similar to those affecting archaeological sites, with the main concerns being damage from wave action and wet-dry

cycling caused by fluctuating lake and river levels. Continuous inundation helps preserve these sites, while exposure due to falling water levels increases risks.

During wet hydrologic conditions, Lake Powell's water levels are expected to remain high, minimizing exposure. As conditions become drier, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain higher water levels than others but still fall below critical thresholds in extremely dry scenarios, exposing more sacred sites. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the highest water levels and protects more sites, especially in dry hydrologic conditions. For the river stretches between Glen Canyon Dam and Lake Mead, and between Hoover Dam and Lake Mohave, annual water releases in wet and average years generally match historical volumes. In critically dry years, releases drop significantly, increasing the risk of exposing sacred and archaeological sites near riverbanks. Below Davis Dam, impacts are minimal due to managed lake elevations and channelized banks.

Indigenous perspectives view cultural and natural resources as interconnected, so any disruption to these links is a potential impact. Along the Colorado River, riparian vegetation and aquatic wildlife are especially important to Native Americans. Woody riparian vegetation is moderately resilient to water fluctuations, but increased variability over several years can reduce these habitats. For Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives best maintain vegetation similar to historical conditions. For Lake Mead, the Maximum Operational Flexibility Alternative performs best, while the Basic Coordination Alternative is closest to historical conditions for Lake Mead and the Hoover Dam to SIB reach. No single alternative matches historical vegetation patterns across all areas, but most alternatives perform better than the CCS Comparative Baseline in most reaches. The Representative Preferred Alternative would be least similar to historic conditions for Lake Powell and Lake Mead.

Lower water levels at Lake Powell benefit endangered river species (Colorado pikeminnow and razorback sucker) by increasing their habitat, especially under the No Action Alternative; however, lower water levels reduce lake habitat for sportfish. Most alternatives (except the Enhanced Coordination and Maximum Operational Flexibility Alternatives) keep Lake Powell below critical thresholds, favoring river habitats. The Enhanced Coordination and Maximum Operational Flexibility Alternatives tend to flood critical habitats, reducing the river habitat value.

For Lake Mead, the No Action Alternative and CCS Comparative Baseline maintain lower water levels; this helps restrict nonnative fish but also limits upstream movement of native fish. The Basic Coordination Alternative offers a moderate balance. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives more often allow Lake Mead to rise above critical thresholds, which can facilitate movement for both native and nonnative fish. The Supply Driven Alternative (LB Pro Rata approach) is most reliable for maintaining Lake Mead above its historical minimum, supporting habitat stability. Overall, the Representative Preferred Alternative provides moderate protection of riverine critical habitat but does not perform as well as the Supply Driven Alternative (LB Pro Rata Approach).

3.14 Recreation

3.14.1 Affected Environment

This section describes existing recreational conditions along the Colorado River system from Lake Powell to the SIB. The analysis focuses on four primary recreational resources: shoreline public use, reservoir boating, river and whitewater boating, and sport fishing. For a more detailed description of these recreational resources, please refer to **Section TA 14.1**, Recreation, Affected Environment.

Geographic Reaches

Lake Powell and Glen Canyon National Recreation Area

Glen Canyon NRA receives approximately three to five million visitors annually (NPS 2025b). Lake Powell is the primary recreational feature within Glen Canyon NRA, and it supports swimming, power boating, houseboating, water skiing, fishing, personal watercraft use, nonmotorized boating, hiking, camping (developed and primitive), and viewing of cultural and geologic resources.

Recreational boating is the dominant activity on Lake Powell, with nearly two million visitors accessing the reservoir by private or rental boats (NPS 2025c). Operability of boat ramps and marinas is highly dependent on the lake's elevation. Several ramps and the Dangling Rope Marina have been closed in the last decade due to low water levels, requiring boaters to concentrate use at fewer facilities and increasing congestion at remaining ramps. The NPS is pursuing new ramps and facility modifications to maintain boating access at lower pool elevations (NPS 2025d).

Access to Rainbow Bridge National Monument has become more limited as lake levels have declined. At elevations below 3,544 feet, concession-operated boat tours can no longer reliably reach the area, and private boaters often must traverse mud, debris, and shallow water between the shoreline and the established trail (NPS 2021b). This has substantially reduced access for many visitors.

Additional shoreline issues at Lake Powell include the following:

- Harmful algal blooms: Increasingly frequent harmful algal bloom events can result in temporary closures of water-based recreation areas to protect public health (Deemer et al. 2023).
- Quagga mussels**:** Established populations of quagga mussels encrust canyon walls, shorelines, boats, and infrastructure. Accumulated shells along beaches can create hazards for visitors and pets and increase facility maintenance needs (NPS 2016).
- Newly exposed lands**:** Declining water levels have exposed approximately 100,000 acres of previously inundated Glen Canyon, revealing arches, side canyons, rock formations, and archaeological sites (Baker 2022; Kolbert 2021). These areas provide new hiking and sightseeing opportunities but are fragile and vulnerable to erosion and vandalism.

Glen Canyon Dam to Lake Mead (Colorado River Corridor)

The 15.5-mile reach downstream of Glen Canyon Dam to Lees Ferry is located within Glen Canyon NRA and is used extensively by anglers, campers, commercial float trips, and private boaters. Warmer water temperatures in recent years have increased use by paddle boarders, kayakers, and canoeists.

Downstream, GCNP begins at the confluence of the Colorado and Paria Rivers. GCNP, a United Nations Educational, Scientific and Cultural Organization World Heritage Site, receives approximately four to six million visitors annually and provides a range of backcountry and river-based experiences (NPS 2025e). Camping along the Colorado River corridor occurs on undeveloped sandbars. The number, size, and suitability of campsites vary over time due to the fluctuating size of sandbars, which are affected by dam operations, tributary floods, vegetation encroachment, and management closures. In general, campsites become fewer or harder to use between HFEs that build sandbars, as vegetation growth, erosion, tributary floods, and aeolian sand movement affect the beaches. The river corridor also borders tribal lands for approximately 108 miles, where the Navajo Nation, Hualapai Tribe, and other tribes manage additional shoreline recreation, such as guided rafting, camping, hunting, and hiking. Access to tribal lands requires permits from the respective tribes.

Lake Mead National Recreation Area

Lake Mead NRA encompasses Lake Mead, Lake Mohave, and the surrounding desert landscapes. Lake Mead NRA receives roughly five to eight million visitors annually (NPS 2025f). The primary recreational activities include boating, fishing, water sports, swimming, camping, hiking, and wildlife viewing. The Overton Wildlife Management Area and other shoreline sites provide additional opportunities for hunting, birdwatching, and photography.

Declining reservoir elevations at Lake Mead have exposed extensive mudflats in several shoreline areas. Visitors attempting to "chase the waterline" on foot or by vehicle for fishing and shoreline access have sometimes become stuck in wet, unstable sediment, necessitating rescues and increasing safety concerns. Multiple launch ramps and some marinas have closed because water levels dropped below critical elevations; these closures have concentrated use at the remaining facilities and contributed to crowding and operational challenges.

As lake temperatures, warm, recreation managers face increasing water quality concerns, including harmful blue-green algal blooms and rare but serious incidents involving *Naegleria fowleri,* which is known as the brain-eating amoeba (NPS 2022).

Lower Colorado River Reaches (Davis Dam to the SIB)

Downstream of Hoover Dam, recreation along the Colorado River is supported by a network of public recreation areas, national wildlife refuges, and state parks, including Davis Camp, Laughlin/Bullhead City, Havasu NWR, Lake Havasu State Park, Bill Williams River NWR, Cibola NWR, Imperial NWR, Martinez Lake, and various small shoreline facilities near Yuma.

Across these reaches, visitors engage in boating, houseboating, fishing, water skiing, swimming, paddling, hunting, hiking, wildlife viewing, and camping. Lake Havasu, in particular, is a high-use destination for motorized boating, angling, spring break, and family recreation. River segments adjacent to NWRs provide more natural settings valued for wildlife viewing, hunting, and low-density boating.

Flows below Hoover Dam are consistently low due to upstream diversions and delivery obligations. As a result, the range of operational changes evaluated across the alternatives is not expected to meaningfully alter flow conditions in a manner that would measurably affect recreation opportunities in this reach. Given the limited variability in flows and the constrained nature of water-based recreation downstream of Parker Dam, a detailed analysis was determined to be unwarranted.

Potential effects in this area would be negligible and would not differ substantially amongst the alternatives. Impacts on recreation below Hoover Dam are not further considered in this EIS.

Recreational Uses

Shoreline Public Use

Shoreline public use in the study area is supported by marinas, boat launch ramps, docks, campgrounds, and access points to major destinations. These facilities provide access for day use, extended boating trips, camping, hiking, and viewing of natural and cultural resources. Fluctuations in reservoir elevations influence the operability and safety of these facilities. Declining water levels can result in temporary or long-term closures of ramps and marinas, relocation or modification of facilities, congestion at remaining access points, and reduced or more difficult access to popular shoreline destinations.

Reservoir Boating

Reservoir boating throughout the system is directly affected by fluctuating water levels. As reservoir elevations decline, navigational hazards (for example, exposed rocks, sandbars, and constricted channels) increase, and safe boating capacities decrease. Management responses include the placement of buoys and markers, installation of warning signs, and formal closure of unsafe areas. Quagga mussel infestations further complicate reservoir boating operations by fouling boats, infrastructure, and shorelines.

In the upstream tributaries to Lake Mead, sediment deposition and receding water levels have created shallow, poorly defined channels. When lake elevations fall below approximately 1,170 feet, the upper end of Lake Mead becomes too shallow for most motorized boats to navigate upstream into the lower Grand Canyon. As Lake Mead has receded, the Colorado River has incised into deposited sediments near Pearce Ferry, forming a new high-hazard rapid (Pearce Ferry Rapid) that blocks upstream motorized navigation and has altered takeout operations.

Large changes in reservoir navigability are not anticipated under the proposed range of operations at Lake Mohave and Lake Havasu because these reservoirs are managed to meet relatively stable monthly target elevations. Lake Mohave and Lake Havasu are therefore not included in the environmental analysis.

River and Whitewater Boating

Whitewater boating is the primary recreational activity on the Colorado River between Lees Ferry and the downstream takeouts at Diamond Creek or Pearce Ferry. Trips may be commercial or private, use a variety of boat types, and range up to 25 days in length. GCNP staff manages river use under the Colorado River Management Plan, which establishes limits on daily launches, group size, trip length, and the timing of motorized and nonmotorized use (NPS 2006).

Navigability and the user experience are influenced by discharge levels, debris fan rapids, and changing channel conditions. Lower flows and increased side-canyon debris can make certain rapids more technically demanding.

Flow levels are a key determinant of whitewater trip quality and safety (Bishop et al. 1987; Shelby et al. 1992; Hall and Shelby 2000; Stewart et al. 2000; Neher et al. 2017). Studies and user surveys indicate that flows below about 10,000 cubic feet per second (cfs) and above about 45,000 cfs are generally

considered less than optimum, while flows between approximately 20,000 and 26,000 cfs are considered optimal for most whitewater users (Shelby et al. 1992; Bishop et al. 1987; Neher et al. 2017). Flows of 8,000–9,000 cfs are regarded as the minimum acceptable levels for safely running trips with passengers (Bishop et al. 1987; Shelby et al. 1992; Stewart et al. 2000).

Downstream of Hoover Dam, the proposed alternatives are not expected to substantially affect river or whitewater boating conditions between Hoover Dam and the SIB.

Sport Fishing

Sport fishing is an important recreational use across the study area. Although specific elevation thresholds for angler satisfaction are not well defined, fishing quality is closely linked to reservoir habitat, water temperature, access via ramps and marinas, and boat navigability.

Lake Powell supports warmwater fisheries, including for striped bass, smallmouth bass, largemouth bass, walleye, catfish, and panfish. Forage species, such as threadfin shad, are sensitive to temperature changes and influence predator populations.

The 15.5-mile tailwater reach below Glen Canyon Dam supports a Blue Ribbon[16] rainbow trout fishery at Lees Ferry. Historically, cold-water releases limited survival and reproduction of warmwater species entrained from Lake Powell. Recent warmer and lower-oxygen releases have increased the risk of establishment and recruitment of nonnative predators, such as smallmouth bass, which potentially reduces trout quality. Please refer to **TA 14**, Recreation, for more information on rainbow trout dynamics in this reach.

Lake Mead and Lake Mohave support diverse warmwater fisheries (for striped bass, largemouth bass, catfish, panfish, and stocked trout). Low reservoir levels have affected hatchery operations at Lake Mead, leading to facility modifications and water supply changes. Farther downstream, Lake Havasu and the lower river reaches support striped bass, largemouth and smallmouth bass, catfish, crappie, sunfish, and other species, with some areas subject to seasonal closures (for example, Cibola Lake) to protect wildlife.

Overall, sport fishing opportunities remain widespread throughout the system but are sensitive to changes in hydrology, water temperature, water quality, and access conditions associated with reservoir elevations and dam operations.

3.14.2 Environmental Consequences

Methodology

Consistent with Reclamation's 2007 Final EIS and 2024 Final SEIS, the analysis builds on traditional threshold-based evaluation methods by integrating DMDU concepts, including robustness heat maps and vulnerability bar plots. These tools highlight how each alternative performs across a wide range of plausible hydrologic futures with regard to shoreline public use facilities, reservoir boating and navigational hazards, whitewater boating, and sport fishing. Refer to **Section 3.2.6**, Decision Making

[16] A Blue Ribbon fishery designation indicates a high-quality recreational fishery that meets specific criteria, including water quality, natural reproduction capacity, and management strategies.

under Deep Uncertainty, for an overview of interpreting the DMDU robustness heat maps and vulnerability bar plots.

Method Used to Assess Shoreline Public Use Facilities

The evaluation of shoreline facilities relies on thresholds provided by the NPS that identify reservoir elevations at which specific marinas, docks, and launch ramps require modification, relocation, or closure. These thresholds serve as impact indicators for the loss or degradation of shoreline public use. Using the DMDU framework, the analysis examines the percentage of futures in which a given alternative maintains a minimum proportion of operable recreational sites throughout the summer high-use season (May 31–August 31). This period was selected because visitation is highest, and operational disruptions have the greatest impact on user experiences and local economies. Representative facilities were selected from Lake Powell and Lake Mead to align with the regional economic modeling (see **TA 16**, Socioeconomics). The analysis then analyzes the performance of alternatives in maintaining representative elevations important for reservoir boating access, including the minimum for safe navigation, a historic low, and the elevation at which all boat ramps and/or planned extensions would become inaccessible.

Method Used to Assess Reservoir Boating and Navigation Hazards

Reservoir boating impacts are analyzed using critical navigational thresholds identified in the 2007 Final EIS and continued in the 2024 Final SEIS. Threshold elevations indicate levels below which safe navigation becomes substantially impaired due to shallow channels, newly exposed hazards, or blocked passageways. DMDU outputs evaluate the frequency with which each alternative avoids falling below these elevations. This approach highlights the reliability of each alternative in maintaining safe boating conditions over multiple hydrologic futures.

Method Used to Assess Whitewater Boating

The evaluation of whitewater boating relies on minimum flow thresholds known to influence navigability, safety, and trip management. Prior studies (Shelby et al. 1992; Stewart et al. 2000) identify 8,000 cfs as the preferred minimum daytime flow for whitewater boating with passengers, 5,000 cfs as a low-flow threshold below which trip disruption and safety hazards increase, and 20,000–26,000 cfs as the preferred range for optimal whitewater boating experiences. DMDU heat maps assess the percentage of futures in which the alternatives maintain flows above the minimum thresholds during the daytime (7:00 a.m. to 7:00 p.m.) across the modeling period.

Methods Used to Assess Ferry and Taxi Boat Services

Thresholds provided by the Utah Department of Transportation (UDOT 2025) identify key elevations required for ferry operations, most notably 3,575 feet. The analysis evaluates whether reservoir elevations under each alternative would sustain these services or require extended closure.

Methods Used to Assess Sport Fishing

Reservoir sport fishing is influenced primarily by habitat availability, shoreline complexity, and thermal conditions. Because no discrete elevation thresholds exist for fishing suitability, DMDU is not used for reservoir sport fishing; instead, the analysis focuses on how general elevation trends under each alternative influence fish habitat.

A more detailed analysis (**TA 8**, Biological Resources – Fish and Other Aquatic Species) using DMDU information was conducted for the Lees Ferry rainbow trout fishery, where water temperature is directly linked to recreational quality and species viability.

Impact Analysis Area

The impact analysis area for recreation aligns with the general analysis area, which encompasses the Colorado River corridor from the full pool elevation of Lake Powell to the SIB. Given the limited flow variability and the constrained nature of water-based recreation downstream of Parker Dam, a detailed analysis below this area not warranted. Potential effects in this area would be negligible and would not differ substantially amongst the alternatives.

Assumptions

- The analysis assumes that the demand for recreational opportunities will either remain constant or increase over time. This assumption forms the basis for evaluating impacts on activities such as reservoir recreation, fishing, and whitewater boating.
- The analysis considers 5,000 cfs and 8,000 cfs as two levels at which commercial and private boaters may experience navigability challenges (Bishop et al. 1987; Stewart et al. 2000; Shelby et al. 1992).
- While HFEs are not directly incorporated into the recreation modeling, actual HFE frequency may differ from that assumed or predicted in other modeling efforts.
- Additional assumptions related to modeling are considered in the analysis, contributing to the accuracy and reliability of the hydrologic models used to anticipate impacts resulting from various actions.

Impact Indicators

- Threshold reservoir elevations
- Threshold river flows
- Water temperatures

Issue 1: How would the management of reservoir elevations affect recreation?

Lake Powell

Shoreline Recreational Facilities

Reservoir elevations exert a direct influence on the operability of Lake Powell's recreational infrastructure. Many of Lake Powell's primary launch ramps, marinas, and courtesy docks become inaccessible or require substantial modification when lake levels fall below the thresholds identified by the NPS (see **Table TA 14-3** in **TA 14**, Recreation). The DMDU results illustrate that in the Full Modeling Period and 2027-2039 subperiod, none of the alternatives would keep at least 60 percent of Lake Powell recreational sites open during the summer months (**Figure TA 14-1** in **TA 14**, Recreation). Based on the planned length of this decision, the Representative Preferred Alternative is unable to meet the preferred minimum performance across the Full Modeling Period and 2027-2039 subperiod, but does so in 30 percent of modeled futures in the 2040-2049 subperiod, and 22 percent of modeled futures in the 2050-2060 subperiod. Under all alternatives, periods of low water would be more likely, which could result in recurring closures of boat launch ramps, restricting marinas to limited operability,

and reducing shoreline access for day users, campers, and boaters. Visitors could experience longer wait times, congested remaining ramps, and reduced access to preferred boating destinations. Taken together, the projected reservoir conditions suggest that under most alternatives, the reliability of Lake Powell's shoreline public use facilities would decline from historical norms.

Boating Navigation

Safe boating access at Lake Powell depends strongly on maintaining reservoir elevations above the 3,620-foot threshold. Elevations below this level expose hazards and constrict navigation channels. The DMDU analysis shows that the Enhanced Coordination and Maximum Operational Flexibility Alternatives offer the greatest robustness at maintaining elevations above this threshold in at least 20 percent of months, doing so in roughly 80 percent of modeled futures. These alternatives would support safer boating conditions under a wider range of hydrologic conditions and preserve access to many of the canyon environments that are central to the Lake Powell recreational experience.

The other alternatives perform moderately to poorly in this regard. The Representative Preferred, No Action, and Basic Coordination Alternatives, achieve the threshold in approximately 60 percent of futures, while the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the threshold in approximately 40 percent of futures. Under these worse-performing alternatives, Lake Powell could experience prolonged periods during which safe passage through major navigation corridors is limited, reducing the quality and quantity of recreational boating opportunities across a wider range of hydrologic futures. All alternatives show poor performance in maintaining a Lake Powell elevation of 3,620 feet or above in 20 percent or more futures, indicating that the long-term return to historically common elevation levels is unlikely.

Sport Fishing

Sport fishing in Lake Powell is sensitive to changes in reservoir elevation because habitat complexity diminishes as water recedes. The Maximum Operational Flexibility and Enhanced Coordination Alternatives, which are more robust at achieving higher median elevations around 3,600 feet, would help preserve a more diverse array of shallow-water habitats favored by desirable warmwater sportfish, including largemouth bass, bluegill, and crappie. Conversely, the lower-elevation alternatives cluster around 3,560 feet and would result in diminished shallow-water habitat, promoting conditions that favor smallmouth bass and reducing the productivity of the fishery for many anglers. Thus, the alternatives that sustain higher average reservoir levels would provide more favorable sport fishing conditions throughout the year.

Ferry and Taxi Boat Services

Ferry and taxi boat services at Lake Powell require relatively high reservoir elevations to maintain safe docking and transit conditions. The ferry becomes inoperable at elevations below 3,575 feet. Because all alternatives frequently fall below this threshold across much of the modeled period, ferry service interruptions or full discontinuation would be a near-constant condition under all operational strategies. Only substantial engineering modifications or relocation efforts would restore reliable ferry service under extended drought conditions.

Lake Mead

Shoreline Recreational Facilities

Lake Mead recreational infrastructure is sensitive to threshold elevations. Many of the reservoir's launch ramps, marinas, and shoreline access points become impaired as water levels retreat, and steep, unstable slopes emerge. The DMDU analysis shows that all alternatives perform poorly at maintaining at least 80 percent of recreational facilities open during the summer season in the Full Modeling Period. The Supply Driven Alternative, particularly the Pro Rata approach, is the most effecting at maintaining this preferred minimum, but only succeeds in 14 percent of modeled futures. While this alternative preserves opportunities at Lake Mead, it also reflects trade-offs for Lake Powell. The Maximum Operational Flexibility Alternative performs moderately well, though not at the same level as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches)

Under all alternatives, including the Representative Preferred Alternative, Lake Mead experiences low reliability in maintaining recreational sites. These deficiencies translate into recurring closures, reduced or eliminated launching opportunities, stranded infrastructure, and a substantial decline in the quality of recreational access. As reservoir conditions deteriorate under these alternatives, visitor safety concerns would increase, and more intensive management interventions would be needed to maintain even modest levels of access.

Boating Navigation

Maintaining Lake Mead above the 1,170-foot threshold is essential for preserving upstream navigation into the lower Grand Canyon. The analysis shows that only the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) provides a high likelihood of maintaining Lake Mead above this level for 10 percent or more of months, with success rates approaching 80 percent of futures. This alternative would help reduce navigation hazards, limit mudflat exposure, and sustain limited upstream boating opportunities.

The other alternatives show weaker performance, with the No Action Alternative and CCS Comparative Baseline exhibiting the poorest performance. Under all alternatives, including the Representative Preferred Alternative, it is likely that large areas of the reservoir would expose thick mudflats and shallow delta formations, making it dangerous or impossible for boaters to access several parts of the reservoir. These conditions would also exacerbate congestion at the limited number of remaining deep-water access points.

Issue 2: How would the management of releases from Glen Canyon Dam affect recreation, including from changes in water temperature?

Whitewater Boating

Whitewater boating conditions below Glen Canyon Dam depend heavily on reliable daytime flows that allow large commercial rafts to safely navigate rapids and manage trip logistics. The analysis shows that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the strongest in maintaining flows at or above the 8,000 cfs minimum threshold, providing favorable conditions in approximately 86 percent of futures. This alternative would make commercial and private boating groups less likely to face low-water hazards, allowing for safer, smoother navigation.

The Basic Coordination Alternative also performs well, while the CCS Comparative Baseline and the No Action, Maximum Operational Flexibility, Representative Preferred, and Enhanced Coordination Alternatives exhibit diminishing performance. The Enhanced Coordination Alternative, in particular, maintains the 8,000 cfs threshold in only 8 percent of futures, indicating substantial vulnerability to flows falling below the preferred safety conditions. As flows weaken, rafting parties could encounter more exposed rocks, shallower rapids, longer portaging distances, and increased risks of boating incidents. These hazards directly affect the quality, reliability, and safety of the Grand Canyon whitewater recreational experience.

When evaluating flows above the 5,000 cfs threshold, below which trip disruption and safety hazards increase, the analysis finds that the Enhanced Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives maintain this threshold in nearly 100 percent of futures. While these flows may not provide optimal conditions, they reduce the likelihood of severe navigational hazards. The other alternatives perform moderately to poorly, elevating risks for boaters and contributing to unpredictable trip conditions.

Overall, the alternatives that maintain higher flows offer substantially better protection of the whitewater recreational quality. Conversely, the alternatives that produce more frequent low-flow conditions increase safety risks, impede access to campsites, and alter trip durations.

Sport Fish Populations

Recreational fishing below Glen Canyon Dam, particularly at Lees Ferry, is highly sensitive to changes in water temperature. Rainbow trout experience thermal stress when temperatures exceed 20 °C (68 °F), while warmwater species, such as smallmouth bass, benefit from elevated temperatures and potentially expand their range.

The Enhanced Coordination Alternative offers the highest likelihood of maintaining cooler water temperatures, meeting the preferred temperature performance in 56 percent of futures. Under this alternative, conditions associated with maintaining the trout fishery would be most favorable. The Maximum Operational Flexibility Alternative also performs moderately well, while the Representative Preferred, Supply Driven (both LB Priority and LB Pro Rata approaches), and the No Action Alternatives perform poorly, allowing temperatures to exceed optimal thresholds in a large proportion of futures.

Under warmer and drier hydrologic futures, all alternatives become more vulnerable to undesirable temperature increases. Under such conditions, rainbow trout populations may decline, and warmwater species may proliferate, potentially altering recreational fishing patterns and diminishing the unique value of the Lees Ferry fishery. Without management interventions, such as cold-water bypass infrastructure, the ability to maintain high-quality trout fishing will remain constrained across all alternatives.

Summary Comparison of Alternatives

The alternatives vary considerably in their ability to sustain recreational resources over the full analysis period as well as all subperiods. The alternatives that favor higher Lake Powell elevations, such as the Enhanced Coordination and Maximum Operational Flexibility Alternatives, offer the greatest benefits for Lake Powell-based recreational resources. These alternatives help preserve access to boat ramps

and marinas, maintain more reliable boating corridors, and sustain more diverse sport fishing opportunities. By contrast, the alternatives that prioritize meeting compact delivery obligations through downstream releases, such as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), perform more poorly for Lake Powell's recreational infrastructure.

At Lake Mead, the pattern is reversed. The alternatives that retain more water downstream, specifically the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), perform best at keeping facilities open and maintaining safe boating conditions. The Maximum Operational Flexibility and Enhanced Coordination Alternatives provide moderate benefits, while the No Action Alternative and the CCS Comparative Baseline offer the least reliable performance for Lake Mead–based recreation. The Representative Preferred Alternative generally performs in the middle of the range of alternatives for both Lake Powell and Lake Mead.

For whitewater boating in the Grand Canyon, the alternatives also yield varying results. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the highest likelihood of meeting the preferred 8,000 cfs flow threshold, supporting safer and higher-quality rafting opportunities. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform poorly in this regard, creating greater risks for boaters and reducing the reliability of commercial trip planning. The Representative Preferred Alternative generally performs in the middle of the range of alternatives for daytime flows.

In terms of water temperature and sport fishing below Glen Canyon Dam, the Enhanced Coordination Alternative performs most favorably, helping sustain the cold-water conditions that support the rainbow trout population. The Maximum Operational Flexibility Alternative also provides moderate support for cooler temperatures. The alternatives that prioritize downstream deliveries at the expense of upstream storage tend to worsen temperature conditions and increase the prevalence of warmwater predators. The Representative Preferred Alternative generally performs in the middle of the range of alternatives for water temperature for rainbow trout.

Overall, no alternative fully protects all recreational resources throughout the Basin under extended drought conditions. Instead, each alternative presents a unique set of trade-offs. Those alternatives that prioritize upstream reservoir elevations tend to support recreation at Lake Powell but reduce downstream releases needed for whitewater boating and temperature control; those that emphasize deliveries to the Lower Basin improve Lake Mead recreation but may worsen recreation conditions in Lake Powell and Lees Ferry. These trade-offs underscore the Basin-wide challenge of managing limited water supplies while simultaneously supporting diverse recreational resources that rely on adequate water levels and river flows.

3.15 Dams and Electrical Power Resources

3.15.1 Affected Environment

This section provides a summary of the infrastructure, spillway conditions, and hydropower capacity and generation of the four primary dams and reservoirs in the analysis area of the Colorado River corridor from the full pool elevation of Lake Powell to the SIB. These four dams and reservoirs are Glen Canyon Dam and Lake Powell, Hoover Dam and Lake Mead, Davis Dam and Lake Mohave, and

Parker Dam and Lake Havasu. For additional information and the full discussion of the affected environment and environmental consequences, please refer to **TA 15**, Dams and Electrical Power Resources.

This section addresses the interplay between reservoir elevations and dam releases, and how they influence dam spillway use, power generation, and capacity. It also provides the context necessary for evaluating the effects of the alternatives on dams and electrical power resources.

Hydropower output depends on how much water passes the turbines and the 'head' (the elevation difference between the reservoir surface and the turbine). The higher the reservoir elevation, the greater the head the water can exert as it passes through the turbines. Higher reservoir elevations allow greater power production, and conversely, if reservoirs drop below a specified elevation (the minimum power pool), power production is not possible.

Keeping the reservoir water level below the spillway crest reduces reliance on spillway infrastructure, preserves the water supply, and maintains flood storage capacity. Maintaining lower reservoir levels allows inflow to be routed through controlled outlets to respond to spring runoff. This section also provides the context for analyzing the effects of the alternatives on electricity rates. Reclamation operates and maintains the Glen Canyon, Hoover, Davis, and Parker Dams, while the Western Area Power Administration (WAPA) is responsible for marketing and transmitting the power generated at these facilities across the Upper and Lower Basins (Reclamation 2007a).

Glen Canyon Dam and Lake Powell

Glen Canyon Dam is located in Page, Arizona, and is a concrete arch dam rising 710 feet with a 35-foot-wide roadway connecting the dam's spillways. The dam's reservoir, Lake Powell, has a water storage capacity of 25.16 maf and a maximum reservoir elevation of 3,711 feet. The dam and reservoir are operated and maintained by Reclamation's Glen Canyon Field Division in Page, Arizona. Refer to **Figure TA 15-3** in **TA 15**, Dams and Electrical Power Resources.

Dam operations are managed to maintain the water surface elevation near or below 3,700 feet, which is the normal operating level. Operational preference is to maintain a water surface elevation below the top of active conservation, 3,700 feet, to minimize the occurrence of flood operations and the need for additional monitoring. Glen Canyon Dam is designed to safely accommodate the probable maximum flood including operating up to the maximum water surface elevation of 3,711 feet. Another important operational consideration is maintaining adequate vacant storage at or below an elevation of 3,684 feet on January 1, which provides the necessary capacity to preserve space for spring runoff inflows.

The Glen Canyon Dam powerplant has eight generators with a maximum combined capacity of 1,320 MW at a reservoir elevation of 3,700 feet (Reclamation 2016). At minimum power pool, the powerplant has an estimated physical capacity of 630 MW. The powerplant's physical capacity to generate power has recently been affected by decreases in Lake Powell reservoir elevations due to drought conditions. The decreases in elevation have led to lower head, which, combined with reduced annual releases, has reduced power generation since 1997. Refer to **Figure TA 15-4** and **Figure TA 15-5** in **TA 15**, Dams and Electrical Power Resources.

Hoover Dam and Lake Mead

Hoover Dam is located in Black Canyon on the Arizona–Nevada state line, approximately 35 miles southeast of Las Vegas, Nevada. The dam and its reservoir, Lake Mead, are operated and maintained by Reclamation's Lower Colorado Basin Dams Office. Hoover Dam is a concrete gravity-arch structure standing 726 feet high with a crest length of 1,244 feet. Lake Mead has a water storage capacity of 30.2 maf and a maximum reservoir elevation of 1,232 feet. Refer to **Figure TA 15-5** in **TA 15**, Dams and Electrical Power Resources.

Under normal conditions, nearly all Colorado River flow passes through the turbines, with the spillways and outlet works used only in exceptional circumstances. The maximum safe channel capacity is estimated to be 40,000 cfs. Current operations aim to keep Lake Mead below 1,219.6 feet as much as possible. While limited operations above this level have occurred historically, it is preferred to minimize time spent in the flood control space. The elevation of the bottom of the spillway drum gate is 1,205.4 feet. Operating below this elevation is desired because elevations above this point rely on mechanical gate function, where the risk of failure increases. The most critical elevation threshold is 1,226.9 feet. This elevation corresponds to a spillway discharge exceeding 40,000 cfs and represents an imminent emergency.

The Hoover Dam powerplant has 17 commercial generators with a maximum combined capacity of 2,074 MW. The powerplant requires a minimum Lake Mead elevation of 950 feet to produce power. At minimum power pool, the powerplant has an estimated capacity of 117 MW. The power-generating capacity of Hoover Dam has been affected by drought conditions. The drop in Lake Mead's elevation has reduced head, lowering electric power output. At Lake Mead elevation 1,035 feet, Hoover Dam's generating capacity decreases from 1,274 MW to 382 MW. Elevations above 1,035 feet in current market conditions, hydropower can be produced at or above market value. With current turbines, if the elevation drops below 1,035 feet, it is estimated that operating costs will exceed the value of the hydropower produced. Please reference **Figure TA 15-6** and **Figure TA 15-7** in **TA 15**, Dams and Electrical Power Resources.

Davis Dam and Lake Mohave & Parker Dam and Lake Havasu

Davis Dam is a 320-foot-tall, rock- and earth-fill gravity dam, rising 140 feet above the Colorado River. The dam spans the border of Arizona and Nevada in Pyramid Canyon and is 67 miles downstream from Hoover Dam. Its dam crest is 1,600 feet long and 50 feet wide. Its reservoir, Lake Mohave, has a water storage capacity of 1.8 maf and a maximum reservoir elevation of 647 feet. Davis Dam is operated and maintained by Reclamation's Davis Dam Field Division, which is part of the Lower Colorado Basin Dams Office.

Parker Dam, commonly known as the 'deepest dam in the world,' is a concrete arch structure with 73 percent of its height below the original stream bed elevation of the Colorado River. The dam is on the Arizona–California border and lies 88 miles downstream from Davis Dam. The dam has a crest length of 856 feet and a width of 39 feet. The dam's reservoir, Lake Havasu, has a storage capacity of 646,200 acre-feet and a maximum reservoir elevation of 450 feet. Parker Dam is operated and maintained by Reclamation's Parker Dam Field Division of the Lower Colorado Basin Dams Office.

Normal releases from Davis and Parker Dams are made through the powerplant turbines with the spillway and outlet works in the closed position. The safe downstream channel capacity on the river is 40,000 cfs.

The Davis Dam powerplant has four 51.75 MW generators and one 48 MW generator for a total capacity of 255 MW. The Parker Dam powerplant has four 30 MW generators, totaling 120 MW, with a discharge capacity of 22,000 cfs (Reclamation 2023c). Drought conditions have had less impact on the capacity at the Davis and Parker powerplants than at the Hoover and Glen Canyon powerplants because the elevations of Lake Mohave and Lake Havasu reservoirs have remained relatively constant. However, drought-induced reductions in river flow have resulted in a decline in electric power generation at these powerplants. Please refer to **Figure TA 15-8** in **TA 15**, Dams and Electrical Power Resources.

Hydroelectric Power Distribution

This section provides a high-level summary of hydroelectric power distribution. Please refer to **TA 15.1.4**, Hydroelectric Power Distribution, in **TA 15**, Dams and Electrical Power Resources, for a more in-depth discussion of the topic and a variety of associated topics, including: scheduling; load following, generation, and regulation; reliability standards; basin funds; emergencies and outages assistance; transmission system; power marketing; Tribal benefit crediting; and rates.

Hydroelectric power generation can be adjusted operationally through a coordinated effort between WAPA and Reclamation. This operational flexibility allows WAPA to quickly and efficiently increase or decrease generation in response to customer demand. WAPA markets long-term firm capacity and energy; short-term, firm capacity and energy; and non-firm energy. WAPA sets rates for Firm Electric Service from federal hydropower projects in its marketing territory, in accordance with Department of Energy regulations and applicable federal statutes. Customers pay rates that align specifically with the project from which they buy power.

WAPA sets rates through a public process (proposal, comment period, and final notice in the Federal Register). WAPA has various wholesale customers, including municipal utilities, federal and state public power facilities, rural electric cooperatives, and tribal entities. Power rates are set so that revenues are sufficient to cover all costs assigned to power within the required time periods. Retail rates are those paid by end users (residential, commercial, and industrial customers of WAPA's wholesale customers). The retail rates charged by not-for-profit entities are normally set to cover system operations and capital costs. As the costs of these individual components change, the retail rates are adjusted to ensure that enough revenue is collected to meet the utility's financial obligations.

3.15.2 Environmental Consequences

This section summarizes the analysis of the effects of the alternatives on the minimum power pool for Lake Powell and Lake Mead; the power capacity of the Glen Canyon Dam and Hoover Dam powerplants; the power generation of the Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants; the spillway use of Glen Canyon Dam and Hoover Dam; and electricity rates and the market value of the electricity.

Spillway use and hydropower capacity of the Davis Dam and Parker Dam are not analyzed because Lake Mohave and Lake Havasu reservoirs have historically remained relatively constant, and their

elevations are expected to remain so under all alternatives. Both Lake Mohave and Lake Havasu would continue to be operated under a rule curve that provides specific target elevations at the end of each month (refer to **Section TA 3.1.8**, Davis Dam to Lake Havasu, in **TA 3**, Hydrologic Resources).

For additional detail and the full analysis of effects, please refer to **Section TA 15.2**, Environmental Consequences, in **TA 15**, Dams and Electrical Power Resources.

Methodology

WAPA's CRSP Python-based (CRiSPPy) model and Reclamation's CRSS model analysis framework informs the basis for the effects analysis. For additional information on the methodology used, please refer to **Section 3.2.6**, Decision Making under Deep Uncertainty; **Appendix A**, CRSS Model Documentation; and **Section TA 15.2.1**, Methodology, in **TA 15**, Dams and Electrical Power Resources.

Impact Analysis Area

The analysis area for Issues 1–4 encompasses the four primary dams in the Colorado River corridor from the full pool elevation of Lake Powell to the SIB: Glen Canyon Dam and Lake Powell reservoir, Hoover Dam and Lake Mead reservoir, Davis Dam and Lake Mohave reservoir, and Parker Dam and Lake Havasu reservoir. The analysis area for Issue 5 consists of the retail electricity customers in Arizona, Colorado, Nevada, New Mexico, Nebraska, Utah, and Wyoming who receive power through local utilities and cooperatives supplied with Glen Canyon Dam power by WAPA. WAPA sells power at the wholesale level, while local utilities and cooperatives distribute that power directly to homes, businesses, and other customers.

Assumptions

All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell, Lake Mead, or both (refer to Appendix S, Additional Description of Alternatives). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

The Lower Basin electrical generation and firm capacity modeling results are direct outputs from CRSS. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation. The Glen Canyon Dam electrical generation and firm capacity modeling results are direct outputs from the CRiSPPy model. For additional information and modeling assumptions, please refer to *CRiSPPy: An Advanced Hydropower Scheduling Tool for the Colorado River Storage Project* (Ploussard et al. 2025). The Glen Canyon Dam rates analysis data was developed by Argonne National Laboratory. Information and modeling assumptions for the rates analysis can be found in *Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project* (Yu et al. 2025).

Impact Indicators

- Lake Powell and Lake Mead Reservoir elevations
- Firm capacity (MW)
- Energy generation (MWhs)
- Spillway releases

- Electricity rates
- The market value of electricity

Issue 1: How do the alternatives impact the frequency at which reservoir elevations drop below the minimum power pool at Lake Powell and Lake Mead?

Minimum power pool is the lowest reservoir elevation level at which a hydropower plant can produce power. The frequency at which reservoir elevations drop below minimum power pool for Glen Canyon Dam/Lake Powell and Hoover Dam/Lake Mead were measured by calculating the percent of futures in which the elevations of the reservoirs achieve the preferred minimum performance of maintaining elevations at or above 3,490 feet and 950 feet respectively (refer to **Figure TA 15-9** and **Figure TA 15-11**); and by using vulnerability figures that display conditions that could cause Lake Powell and Lake Mead to drop below these thresholds (3,490 feet and 950 feet respectively), representing undesirable performance when elevations fall below minimum power pool in one or more months (refer to **Figure TA 15-10** and **Figure TA 15-12**).

The Maximum Operational Flexibility Alternative would provide the greatest power pool robustness for both Lake Powell and Lake Mead. For Lake Powell, the Enhanced Coordination Alternative would provide the second-highest level of power pool, while the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would provide the lowest. Conversely, for Lake Mead, the Supply Driven Alternative (LB Pro Rata approach) would provide the second-highest level of power pool, followed by the Enhanced Coordination Alternative. For Lake Mead, the least robust alternative is the No Action Alternative.

Under the driest hydrologic conditions, the Maximum Operational Flexibility and Enhanced Coordination Alternatives would provide the most robust outcomes for maintaining Lake Powell elevations above the preferred threshold, whereas the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the No Action Alternative would provide the least. For Lake Mead, the Maximum Operational Flexibility Alternative, Supply Driven Alternative (LB Pro Rata approach), and Enhanced Coordination Alternative would provide the greatest robustness, while the No Action Alternative would provide the least.

For Lake Powell elevation power pool robustness, the Representative Preferred Alternative exhibits a better performance than the No Action, CCS Comparative Baseline, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) alternatives for the full modeling period. For Hoover Dam, the Representative Preferred Alternative is more robust than all alternatives except the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives in the 2027-2039 modeling period.

Issue 2: How would the alternatives impact the firm capacity of the Glen Canyon Dam and Hoover Dam powerplants?

Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates. Firm capacity is measured in MW. This section considers how the different alternatives affect the annual firm capacity of the hydropower plants at the Glen Canyon Dam and Hoover Dam for the month of August. The analysis uses boxplots to display August firm capacity at both dams across five categories of Lees Ferry natural flow conditions based on the preceding 3-year average Lees Ferry natural flow, as shown in **Figure TA 15-**

14 and **Figure TA 15-15** in **TA 15**, Dams and Electrical Power Resources. The boxplots illustrate firm capacity over a 3-year period for each flow category, allowing comparison of alternative performance across a range of hydrologic conditions.

For Glen Canyon Dam, the firm capacity would be highest in the Average Flow Category (12.0–14.0 maf) under the Enhanced Coordination Alternative, followed by the CCS Comparative Baseline, and would be lowest under the No Action Alternative. Under the other action alternatives, in the Average Flow Category there would be a similar capacity of between 675 and 725 MW. In the Critically Dry Flow Category (4.46–10.0 maf), the No Action Alternative, Basic Coordination Alternative, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and CCS Comparative Baseline would show a wide range of interquartile values, with all having the potential for capacity to drop to 0 MW. In the Critically Dry Flow Category, the capacity for every alternative and the CCS Comparative Baseline would be below 725 MW.

For Hoover Dam, in the Average Flow Category (12.0–14.0 maf), the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Enhanced Coordination Alternative, and Maximum Operational Flexibility Alternative would yield the highest capacity, each exceeding 1,250 MW. The CCS Comparative Baseline, No Action Alternative, and Basic Coordination Alternative all would have wide interquartile ranges. The No Action Alternative would result in a lower capacity in the Average Flow Category. In the Dry Flow Category (10.0–12.0 maf), the Supply Driven Alternative (LB Pro Rata approach) would provide the highest capacity and the smallest interquartile range. All other action alternatives would have wide interquartile ranges and varying capacity in the Dry Flow Category. The No Action Alternative and the CCS Comparative Baseline would have lower capacity in the Dry Flow Category. In the Critically Dry Flow Category (4.46–10.0 maf), the Supply Driven Alternative (LB Pro Rata approach) would have the highest capacity but, like the other action alternatives, would have a wide interquartile range under the Critically Dry Flow Category. Under the Critically Dry Flow Category, the Supply Driven Alternative (LB Priority approach) and Basic Coordination Alternative would have the potential to drop to 0 MW. The CCS Comparative Baseline and the No Action Alternative would produce the lowest capacity in the Critically Dry Flow Category, and they both would have the potential to drop to 0 MW.

Issue 3: How would the alternatives impact the energy generation of the Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants?

Energy generation is the amount of energy created over a certain period, measured in MWh. Energy generation is dependent on reservoir head and water release volume. The model inputs used to develop the boxplot figures in this analysis simulated releases and lake reservoir elevations to calculate estimated energy generation for the Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants. The boxplots summarize results by five flow categories based on the preceding 3-year average Lees Ferry natural flow. Please refer to **Figure TA 15-17**, **Figure TA 15-18**, **Figure TA 15-19**, and **Figure TA 15-20** in **TA 15**, Dams and Electrical Power Resources.

At Glan Canyon Dam powerplant, under the Average Flow Category (12.0–14.0 maf; refer to **Figure TA 15-17** in **TA 15**, Dams and Electrical Power Resources), the Maximum Operational Flexibility and Enhanced Coordination Alternatives performed slightly above the historical average energy generation value. The median energy generation for the other alternatives remain near the historical average energy generation of approximately 3.4 million MWhs. In the Critically Dry Flow Category (4.46–10.0

maf), the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives would have the highest median power generation (approximately 2 million MWhs) and the smallest interquartile ranges. The Basic Coordination and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), along with the CCS Comparative Baseline, would have larger interquartile ranges and lower levels of power generation.

For the Hoover Dam powerplant (as shown in **Figure TA 15-18** in **TA 15**, Dams and Electrical Power Resources), in the Average Flow Category, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) experience the highest median value that is comparable to the historic median value of 3.3 million MWhs. Most alternatives have interquartile ranges that fall within the historic median value. The No Action Alternative would have the greatest interquartile range and the lowest level of power generation of approximately 2 million MWhs. In the Critically Dry Flow Category, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would result in the highest median generation, followed by the Maximum Operational Flexibility, Representative Preferred, Enhanced Coordination, and the Basic Coordination Alternatives. In the Critically Dry Flow Category, the No Action Alternative would produce the least amount of power and, like the CCS Comparative Baseline and the Basic Coordination Alternative, have interquartile ranges that have potential to drop to 0.0 million MWh.

For the Davis Dam powerplant (as shown in **Figure TA 15-19** in **TA 15**, Dams and Electrical Power Resources), in the Average Flow Category, the No Action Alternative, and the CCS Comparative Baseline would result in the highest median generation, comparable to the historic median value of 1.1 million MWhs. The Enhanced Coordination Alternative experienced the lowest median value of approximately 0.95 million MWhs. In the Critically Dry Flow Category, the CCS Comparative Baseline, Basic Coordination Alternative, and Supply Driven Alternative (LB Priority approach) result in the highest median generation values. The alternatives with the lowest median generation value are Enhanced Coordination and Maximum Operational Flexibility. The No Action Alternative and CCS Comparative Baseline show the widest interquartile ranges, reflecting greater variability in annual energy generation under these flow conditions. Approximately 25 percent of the values fall at or below 0.75 million MWh.

For the Parker Dam powerplant (as shown in **Figure TA 15-20** in **TA 15**, Dams and Electrical Power Resources), in the Average Flow Category, the CCS Comparative Baseline, No Action, and Basic Coordination Alternatives performed comparability to the historical median generation value of 0.42 million MWhs. Enhanced Coordination Alternative and Supply Driven Alternative (LB Pro Rata approach) would have lowest median generation of approximately 0.37 and 0.38 million MWhs and wider interquartile ranges. In the Critically Dry Flow Category, the Basic Coordination Alternative and Supply Driven Alternative (LB Priority approach) would result in the highest median values of energy generation with the narrowest interquartile ranges. The Enhanced Coordination Alternative would experience the lowest median value for energy generation at approximately 0.32 million MWhs, followed by the Supply Driven Alternative (LB Pro Rata approach) at approximately 0.36 million MWhs.

Issue 4: How would the alternatives impact spillway use?

Spillway infrastructure is affected by the frequency of high reservoir elevations, which vary greatly between the alternatives. High reservoir elevations for extended durations pose a risk to spillway

infrastructure. This analysis compares the various action alternatives with the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Lake Powell pool elevations
- Lake Mead pool elevations

Keeping the reservoir below the spillway crest minimizes the infrastructure wear and tear and, preserves water supply and flood storage. Maintaining lower reservoir levels allows inflow to be routed through controlled outlets and respond to spring runoff. Maintaining Lake Powell elevation below 3,684 feet, the Representative Preferred Alternative is the most robust, meeting the preferred minimum in 86 percent of futures under the full modeling period. For the 2027-2039 model, the CCS Comparative Baseline is the highest performing alternative, meeting the preferred minimum in 91 percent of futures. The Enhanced Coordination, Maximum Operation Flexibility, and No Action Alternatives for the full modeling period and 2027-2039 model performed on average lower than any of the other alternatives (see **Figure TA 15-21** in **TA 15**, Dams and Electrical Power Resources). Maintaining Lake Powell elevation below 3,700 feet, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would be the most robust at meeting the preferred minimum in 66 percent of futures in the full modeling period. For the 2027-2039 model, the CCS Comparative Baseline and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meet the preferred minimum in 82 percent of futures. The Enhanced Coordination and Maximum Operation Flexibility Alternatives for the full modeling period and 2027-2039 model performed on average lower than any of the other alternatives (see **Figure TA 15-23** in **TA 15**, Dams and Electrical Power Resources). Spillway release avoidance at Glen Canyon Dam for the full modeling period meets the preferred minimum in 78 percent of futures under the Representative Preferred and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. For the 2027-2039 modeling period, the CCS Comparative Baseline meets the preferred minimum in 90 percent of futures, with Representative Preferred and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives following in 89 percent of futures (see **Figure TA 15-25** in **TA 15**, Dams and Electrical Power Resources).

For Hoover Dam/Lake Mead, maintaining elevation at 1,205.4 feet for spillway crest avoidance, the No Action Alternative and CCS Comparative Baseline, would be the most robust in meeting the preferred minimum under the full modeling period in 85 and 84 percent of futures, respectively. The worst performing alternative in the full modeling period was the Supply Driven Alternative (LB Pro Rata approach) at 43 percent of futures. For the 2027-2039 period, the No Action Alternative and CCS Comparative Baseline met the preferred minimum in 93 percent of futures. The lowest performing was the Supply Driven Alternative (LB Pro Rata approach) at 68 percent of futures (see **Figure TA 15-27** in **TA 15**, Dams and Electrical Power Resources). For Hoover Dam/Lake Mead to not exceed 1,219 feet in the full modeling period, the CCS Comparative Baseline and No Action and Basic Coordination Alternatives meet the preferred minimum in 99 percent of futures, followed by the Enhanced Coordination Alternative in 91 percent of futures. The least robust alternative for the full modeling period was the Supply Driven Alternative (LB Pro Rata approach) at 79 percent. In the 2027-2039 modeling period, the CCS Comparative Baseline, No Action, Basic Coordination, Enhanced Coordination, and Maximum Operational Flexibility Alternatives meet the preferred minimum in 93 percent or more of futures. The Supply Driven Alternative (LB Pro Rata approach) was the least robust at 84 percent of futures (see **Figure TA 15-29** in **TA 15**, Dams and Electrical Power Resources). For Hoover Dam/Lake Mead to not exceed 1,226.9 feet in the full modeling

period, the CCS Comparative Baseline and No Action Alternative meet the preferred minimum in 92 percent of futures and followed by Basic Coordination in 91 percent of futures. The least robust alternative for the full modeling period was the Supply Driven Alternative (LB Pro Rata approach) at 70 percent. In the 2027-2039 modeling period, the CCS Comparative Baseline and No Action Alternative meet the preferred minimum in 98 percent or more of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) was the least robust in 89 and 88 percent of futures (see **Figure TA 15-31** in **TA 15**, Dams and Electrical Power Resources).

Issue 5: How would changes in energy generation impact electricity rates and the market value of electricity?

Glen Canyon Dam

Argonne National Laboratories and WAPA's report, "Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project" (Yu et al. 2025), assessed the relative impacts of various Glen Canyon Dam hydrological scenarios on the CRSP's Firm Electric Service rates. This analysis utilized an advanced simulation tool to estimate future generation production along with a stepwise rate adjustment framework. This framework is consistent with CRSP's obligation to remain financially self-sustaining and deliver cost-based power services (DOE, 2025) and was used to evaluate the rate implications of simulated Glen Canyon Dam-only generation outcomes. It is important to note that CRSP's FES rates encompass hydropower generation resources beyond Glen Canyon Dam; therefore, the identified rate impacts are theoretical, representing uncertainty associated with future Glen Canyon Dam hydrological conditions. The report found that the Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently yielded more favorable hydropower generation outcomes, associated with higher electricity production. These alternatives also indicated fewer rate adjustments, smaller average increases per adjustment, and substantially lower maximum rate increases when an increase was identified. Specifically, under wet or average hydrologic conditions, these alternatives led to results similar to or slightly better than other alternatives. Under dry hydrologic conditions, they resulted in substantially smaller rate increases and less frequent rate adjustments. Overall, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are identified as entailing less adverse economic impact on U.S. electricity consumers and providing greater protection against extreme adverse outcomes compared to the other five alternatives. The modeling framework and key methodological choices supporting these findings, as documented in Yu et al. (2025), included comprehensive data on CRSP's plant characteristics, hydrological conditions, Argus forward prices, and CRSP's power purchase and sales transactions. Another important point to note is that the rate adjustment framework used in the study is a simplified version of actual rate-changing processes, as it is based solely on assumed revenue requirements and simulated electricity production. Consequently, it provides a directional analysis for comparing policy scenarios rather than forecasting actual consumer rates, requiring careful contextualization to avoid misinterpretation. Extreme hydrological conditions, potentially leading to very low or even zero simulated electricity production, can result in a non-trivial subset of degenerate results, projecting unrealistic rate increases or decreases. These extreme events, particularly zero electricity production from Glen Canyon Dam, are unprecedented and fall outside the scope of the current analysis framework, as they cannot be resolved through standard rate adjustments.

For the Glen Canyon Dam powerplant, changes in energy generation across the modeled flow categories directly influenced the market value of hydropower production. Under the Wet Flow

Category, the Representative Preferred Alternative achieves the highest median annual generation value (approximately $350 million), while the CCS Comparative Baseline and No Action Alternative have the lowest (approximately $260 million). Under the Average Flow Category, all alternatives perform similarly, although the Maximum Operational Flexibility Alternative produces the highest median value (approximately $230 million). Under Critically Dry Flow Conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best, maintaining the highest median values (approximately $125 million) and lowest variability, whereas the remaining alternatives exhibit greater variability and include outcomes with a 25 percent probability of annual generation values declining to $0 (see **Figure TA 15-34** in **TA 15,** Dams and Electrical Power Resources).

Hoover Dam

Hoover Dam provides federally marketed hydropower to Arizona, California, and Nevada through the Boulder Canyon Project, managed by WAPA. Funding for the project's operation, maintenance, and capital costs is entirely self-supported by these hydropower sales to contracted entities, requiring no taxpayer funding. Historically, cost-based rates kept Hoover power lower than regional wholesale market alternatives. Under this framework, customers pay a fixed annual base charge to cover these costs, allocated by contract share rather than actual generation. However, as declining water levels reduce generation output, the unit cost of the remaining power rises. This creates a financial swing: when generation drops sufficiently, Hoover's unit cost surpasses market rates, making the power uneconomical and potentially forcing contracted entities to abandon their long-term contracts.

Figure TA 15-35, in **TA 15,** Dams and Electrical Power Resources, shows the market value of hydropower at Hoover Dam. The analysis uses a dollar-per-MWh rate from the Lower Basin Dams Office (WY 2027 data), applied to modeled energy generation from CRSS. Market projections are based on the Preceding 3-Year Average Lees Ferry Natural Flow. Values depend on reservoir elevation with value increasing at elevations above 1,035 feet and lower below it. Under Average Flow conditions, most alternatives have median market values around $200 million. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives maintain higher medians with moderate variability. In contrast, the No Action and Basic Coordination Alternatives show lower medians and greater variability. Critically Dry conditions produce the lowest annual values. The Maximum Operational Flexibility, Basic Coordination, Representative Preferred, and Supply Driven (LB Pro Rata approach) Alternatives show the highest medians ($75–$150 million) and least variability, although the Basic Coordination Alternative has a wider spread. Other alternatives and the CCS Comparative Baseline show larger variability, with lower-end values dropping to $0.

Davis and Parker Dam

The Parker Davis Project is a federally operated system combining the Parker and Davis Dam hydroelectric facilities and transmission infrastructure on the Colorado River. Reclamation operates and maintains the dams and powerplants, while the WAPA markets and transmits the generated electricity to customers under long term contracts.

WAPA sets rates using a cost-recovery framework designed to recover annual project costs including operations, maintenance, replacements, and federal investment repayment. WAPA currently markets the project as a firm, fixed monthly delivery obligation, purchasing supplemental wholesale power to meet this commitment. Declining generation has increased the need for supplemental power, driving

significant rate increases due to market price volatility. Starting in October 2028, a new marketing plan will align APA's delivery obligations with hydropower availability. This change will potentially create a financial swing. If generation drops sufficiently, Parker-Davis Project rates could surpass market rates, making the power uneconomical and potentially forcing contracted entities to abandon their long-term contracts.

WAPA sets rates using a cost-recovery framework designed to recover annual project costs including operations, maintenance, replacements, and federal investment repayment. WAPA currently markets the project as a firm, fixed monthly delivery obligation, purchasing supplemental wholesale power to meet this commitment. Declining generation has increased the need for supplemental power, driving significant rate increases due to market price volatility. Starting in October 2028, a new marketing plan will align WAPA's delivery obligations with hydropower availability. This change will potentially create a financial swing. If generation drops sufficiently, Parker-Davis Project rates could surpass market rates, making the power uneconomical and potentially forcing contracted entities to abandon their long-term contracts.

Figure TA 15-36 in **TA 15**, Dams and Electrical Power Resources, shows the annual market value of hydropower at Davis Dam based on CRSS modeling of generation and an assumed dollar-per-MWhs rate to determine the financial value (in millions of dollars). The results are grouped by preceding 3-year average Lees Ferry natural flow to show how fiscal value is influenced by hydrology for each alternative. Differences in fiscal value are driven by differences in releases across the alternatives (see **Figure TA 3-26** for calendar year releases from Davis Dam). Under the Average Flow Category, the No Action Alternative and CCS Comparative Baseline show similarly high median market values of approximately $47 million and $46 million dollars annually, respectively. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Enhanced Coordination Alternatives have the lowest median value at approximately $42 million. Under the Critically Dry Flow Category, the Maximum Operational Flexibility, Representative Preferred, and Enhanced Coordination Alternatives had the lowest median market values (approximately $35 million), while the Basic Coordination Alternative had the highest median market value at approximately $40 million.

Summary Comparison of Alternatives

No Action

For Glen Canyon Dam and Lake Powell, the No Action Alternative is among the least robust alternatives, with a relatively high likelihood of dropping below minimum power pool and experiencing losses in firm capacity and energy generation under dry conditions. Market values are generally lower and more variable across flow conditions.

For Hoover Dam and Lake Mead, the No Action Alternative is the least robust alternative for maintaining elevations above minimum power pool and for preserving high-head turbine operations. However, it performs favorably for avoiding high Lake Mead elevations and spillway-related risks.

At Davis and Parker Dams, the No Action Alternative generally performs well for energy generation and market value under moderately wet to dry conditions but experiences increased variability and reduced performance under critically dry conditions.

Basic Coordination

For Glen Canyon Dam, the Basic Coordination Alternative provides moderate performance for maintaining minimum power pool but remains more vulnerable to dry hydrologic conditions than the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Firm capacity, energy generation, and market value are generally moderate but become increasingly variable under dry conditions.

For Hoover Dam, the Basic Coordination Alternative performs moderately well in maintaining elevations above minimum power pool protection. Firm capacity, energy generation, and market value remain moderate under wet and average flow conditions but become increasingly variable under dry and critically dry conditions, resulting in less consistent performance.

For Davis and Parker Dams, energy generation and market value remain generally consistent across most flow categories, with performance comparable to many of the other action alternatives. Because reservoir elevations at Lake Mohave and Lake Havasu remain relatively stable, differences among alternatives are modest, although generation and market value decline and become more variable under dry and critically dry conditions. In addition, the Basic Coordination Alternative performs favorably in limiting high reservoir elevations and spillway-related risks at both Lake Powell and Lake Mead, providing a balanced approach between hydropower performance and reservoir management objectives.

Enhanced Coordination

For Glen Canyon Dam, the Enhanced Coordination Alternative is one of the strongest-performing alternatives, maintaining minimum power pool in a high percentage of futures and consistently supporting relatively high firm capacity, energy generation, and market value across all flow categories. It is one of the few alternatives that avoids 0 firm capacity outcomes under critically dry conditions.

For Hoover Dam, Enhanced Coordination provides high robustness for maintaining elevations above minimum power pool and supports relatively stable generation and market value. Although total generation is sometimes lower than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) under wet conditions, performance remains strong under dry and critically dry conditions.

For Davis and Parker Dams, energy generation and market value are generally comparable to other alternatives under wetter conditions, although performance may be somewhat lower than other alternatives under the driest flow categories. Overall, the Enhanced Coordination Alternative provides a strong balance of hydrologic robustness, generation performance, and market value while minimizing vulnerability to dry conditions.

Maximum Operational Flexibility

For Glen Canyon Dam, the Maximum Operational Flexibility Alternative provides the highest robustness for maintaining minimum power pool and consistently avoids 0 firm capacity conditions. It produces among the highest energy generation and market values under dry and critically dry conditions while maintaining low variability.

For Hoover Dam, this alternative provides some of the highest robustness for maintaining minimum power pool, strong firm capacity, and relatively stable energy generation and market values across

hydrologic conditions. While not always producing the highest generation during wet conditions, it consistently performs well as hydrologic conditions become drier.

For Davis and Parker Dams, energy generation and market values are generally moderate relative to other alternatives. Overall, Maximum Operational Flexibility is among the best-performing alternatives for reliability, generation stability, and market value across the system, particularly under adverse hydrologic conditions.

Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative

For Glen Canyon Dam, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) generally provides high firm capacity and energy generation under wet and moderately wet conditions but are more vulnerable to low reservoir elevations than the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Market values are high under favorable hydrology but become more variable as conditions dry.

For Hoover Dam, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) provides some of the highest firm capacity, energy generation, and market value outcomes across most flow categories. The Supply Driven Alternative (LB Pro Rata approach) performs particularly well at maintaining Lake Mead elevations above minimum power pool, although both approaches become more variable under dry conditions.

For Davis and Parker Dams, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) generally produces the highest energy generation and market values under wet conditions. Under drier conditions, performance becomes more comparable to other alternatives, with the Supply Driven Alternative (LB Pro Rata approach) sometimes produces among the lower generation outcomes. Spillway-related performance is strongest at Lake Powell but weakest at Lake Mead, where the alternatives result in more time at high reservoir elevations.

Overall, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maximizes generation and market value, particularly at Hoover Dam, but involve tradeoffs related to reservoir elevation robustness and performance under increasingly dry conditions.

Representative Preferred Alternative

For Glen Canyon Dam, the Representative Preferred Alternative performs particularly well under wet conditions, producing the highest market values and strong firm capacity. Under dry and critically dry conditions, it continues to provide relatively high energy generation and market values, although performance is generally slightly below the Enhanced Coordination and Maximum Operational Flexibility Alternatives.

For Hoover Dam, the Representative Preferred Alternative provides strong minimum power pool performance, relatively stable generation, and competitive market values across most flow categories. While it does not consistently achieve the highest firm capacity or energy generation, it generally performs in the upper tier of alternatives.

For Davis and Parker Dams, performance is generally comparable to other action alternatives, with moderate-to-high energy generation and market values across hydrologic conditions. From a spillway

and reservoir-elevation perspective, it performs among the stronger alternatives at Lake Powell and in the middle range at Lake Mead.

Overall, the Representative Preferred Alternative provides a balanced combination of reservoir protection, power generation, market value, and infrastructure performance. This alternative performs well across all major measures and avoids many of the tradeoffs associated with alternatives focused on a single objective.

3.16 Socioeconomics

3.16.1 Affected Environment

This section briefly discusses key current conditions of economic indicators—such as employment, labor income, and unemployment rates—as well as social and nonmarket values. For additional details on these current conditions, refer to **Section TA 16.1**, Affected Environment, in **TA 16**, Socioeconomics. For overall demographic information, such as population and race and ethnicity data, refer to **Section TA 16.1.4**, Demographics, and **Section TA 17.1**, Affected Environment, in **TA 17**, Population and Land Use. For information on tribal populations and interests, refer to **TA 13**, Tribal Resources**.**

The socioeconomic analysis area includes counties in Arizona, California, Nevada, and Utah (see **Map TA 16-1**). The Arizona analysis area consists of Apache, Coconino, Gila, Graham, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, Yavapai, and Yuma Counties. The California analysis area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. The Nevada analysis area consists solely of Clark County. The Utah analysis area consists of Garfield, Kane, and San Juan Counties. These analysis areas include the following:

- Counties that are directly adjacent to Lake Powell, Lake Mead, or the mainstream Colorado River
- Counties that receive water from the Colorado River and in which impacts from Colorado River shortages would likely occur
- Counties that have ties to recreation-related economic activity on the Colorado River
- Counties where tribal reservations affected by Colorado River shortages are located
- Counties where tribal reservations that have ties to tribal water rights settlements involving CAP water and non-CAP Colorado River water delivered through the CAP are located.

The analysis of impacts on economic and social conditions due to changes in agricultural production includes Arizona, California, and Nevada. The analysis of economic impacts from changes in recreation use includes Arizona, California, Nevada, and Utah. The impact analysis on ecosystem services and nonmarket values includes Arizona, California, Nevada, and Utah.

Baseline Economic Conditions

The following section provides an overview of county-level data for baseline economic conditions, including data on employment, labor income, unemployment rates, poverty, and the market value of agricultural production in the analysis areas. The county-level data do not distinguish between the

water sources that were used in support of the economic conditions presented, which may include a combination of the mainstream Colorado River, CAP, and other water sources.

Arizona

In 2022, total employment in the analysis area counties (about 4.2 million jobs) represented approximately 98.1 percent of total employment in Arizona. Farm employment in the 12 counties totaled almost 26,000 jobs in 2022 (about 0.6 percent of total analysis area employment). While total employment in the analysis area increased from 2010 employment levels by about 36 percent, farm employment decreased during the same time period by about 2 percent (see **Table TA 16-1** and **Table TA 16-2**). Employment in the arts, entertainment, and recreation sector totaled approximately 84,000 jobs (or 2.0 percent of the total employment in the analysis area) in 2022, which was an increase of about 27 percent from the number of jobs in 2010.

In 2022, the total market value of agricultural products sold in the Arizona analysis area contributed $4.8 billion to Arizona's economy, which was about 91 percent of the market value of agricultural products sold in the state. Across Maricopa, Pima, and Pinal Counties, the market value of crops sold in 2022 ranged from about $87.1 million in Pima County to about $742.6 million in Maricopa County (USDA 2024; see **Table TA 16-5**). In 2022, the Maricopa, Pima, and Pinal Counties accounted for approximately 55 percent of Arizona's harvested acres of hay and haylage crops, 65 percent of the state's harvested acreage of cotton, and 44 percent of the harvested wheat acreage. The three western Arizona counties that are located along the Colorado River—Mohave, La Paz, and Yuma Counties—accounted for approximately 33 percent of the statewide harvested hay and haylage acreage, 78 percent of the harvested acres of vegetable crops, and 53 percent of the harvested wheat acres in 2022. Yuma County alone accounted for 77 percent of the state's total harvested acres of vegetable crops (USDA 2024). Additional information on irrigated agricultural acreage within the analysis area is provided in **TA 17**, Population and Land Use.

California

In 2022, total employment in the analysis area counties (about 13.9 million jobs) represented approximately 55 percent of total employment in California. Farm employment in the six counties totaled almost 31,000 jobs in 2022 (about 0.2 percent of the total analysis area employment). Farm employment made up a larger percentage of total employment in Imperial County than the rest of the counties in the analysis area, with 4.7 percent of total employment coming from the farm sector in Imperial County (BEA 2024). While total employment in the analysis area increased from 2010 employment levels by about 30 percent, farm employment decreased by about 9 percent during the same time period (see **Table TA 16-7** and **Table TA 16-8**).

In 2022, the total market value of agricultural products sold in the California analysis area contributed $6.1 billion to California's economy. The market value of crops sold in the analysis area was about $4.7 billion, ranging from about $69.5 million in Orange County to about $2.2 billion in Imperial County (USDA 2024; see **Table TA 16-11**). In 2022, the California analysis area counties accounted for approximately 30 percent of California's harvested acres of hay and haylage crops, 16 percent of the state's harvested acreage of vegetables, and 35 percent of the harvested wheat acreage (USDA 2024).

Nevada

In 2022, total employment in Clark County (about 1.5 million jobs) represented approximately 74 percent of the total employment in Nevada. In 2022, employment in the arts, entertainment, and recreation sector totaled almost 47,000 jobs, or 3.1 percent of the total employment in the county. Farm employment represented less than 0.1 percent of total employment, with a little more than 400 jobs (see **Table TA 16-13**).

Approximately 8.4 percent of Nevada's land area in 2022 was used for agricultural purposes (on cropland, pastureland, woodland, or other; USDA 2024). In 2022, the market value of agricultural products sold in Nevada contributed nearly $1 billion to the statewide economy.

Utah

In 2022, total employment in the analysis area counties (about 17,000) represented approximately 1.0 percent of the total employment in Utah. In 2022, employment in the arts, entertainment, and recreation sector totaled approximately 400 jobs (or 2.4 percent of the total employment in the analysis area) and represented 6.0 percent of employment in Kane County (see **Table TA 16-16**).

Economic Contributions from Recreational Use

Total economic output for lake-based recreation in the analysis area was $358 million from Lake Mead NRA and $670 million from Glen Canyon NRA, and the total economic output for river-based recreation was $1,022 million in Grand Canyon National Park (GCNP; see **Table TA 16-19** and **Table TA 16-20**).[17] These amounts reflect total economic output from visitor spending made by local and nonlocal visitors. Spending by nonlocal visitors represents an influx of dollars from outside the local economy. In addition, nonlocal visitors typically have higher levels of spending on food, lodging, and other activities on a per-trip basis. Over 88 percent of recreation spending in Glen Canyon NRA, Lake Mead NRA, and GCNP came from nonlocal visitors (Flyr and Koontz 2024). In 2023, Glen Canyon NRA recreation spending supported 6,300 jobs, Lake Mead NRA recreation supported 3,131 jobs, and GCNP recreation supported 10,064 jobs (Flyr and Koontz 2024; see **Table TA 16-21** and **Table TA 16-22**).

In addition to general recreation sector contributions, visitor use supports concessionaires, including those associated with water-based recreation, such as commercial river trips. In GCNP, commercial river trips hosted about 17,000 passengers in 2023 (a slight decrease from about 20,000 passengers in 2022 and 21,000 passengers in 2021). From these river trips, river concessionaires contributed $63.6 million in 2023 in gross revenue (a decrease from $66.4 million in 2021, in 2023 dollars), representing 29 percent of the total concessionaire revenue at GCNP. River concessionaire franchise fees paid to the NPS in 2023 totaled $6.25 million, of which 80 percent stays at GCNP.[18]

NWRs also support economic contributions through expenditures from recreational visitors, such as entrance fees, lodging near the refuges, and purchases from local businesses for items to pursue their

[17] Economic output for recreation is the total estimated value of the production of goods and services supported by visitors' spending, including the direct, indirect, and induced impacts. Direct impacts occur when businesses sell goods and services to area visitors. Indirect impacts are economic activity supported when businesses purchase supplies and services from other local businesses. Induced impacts occur when employees use their income to purchase goods and services in the local economy.

[18] Laurie Dyer, NPS supervisory concessions management specialist in the Commercial Services Division at GCNP, personal communication provided on September 27, 2024.

recreational experience. In 2017, the Imperial NWR supported about $11.1 million in total economic output (see **Table TA 16-23**).

For additional information on recreation and levels of use in the analysis area, refer to **TA 14**, Recreation.

Social and Nonmarket Values

Nonmarket values refer to resource benefits that are not captured in market transactions or traditional economic measures. Along the Colorado River, these values include the enjoyment of natural scenery, opportunities for recreation and solitude, preservation of landscapes, and the symbolic and ecological importance of the river itself. Such values are important for understanding how river operations affect people's experiences, sense of place, and well-being, even when no direct economic exchange is involved. Place-based communities—such as gateway communities—and non-place-based communities—such as individuals who may never visit but who value the river—derive nonmarket values from the Colorado River, including cultural identity, recreation quality, aesthetics, and existence values. These values often differ by type of community as well as an individual's beliefs. Understanding these values provides important context for assessing potential changes in access and the quality of nonmarket and social values under the post-2026 operational alternatives. For additional details on these social and nonmarket values, refer to **Section TA 16.1**, Affected Environment.

3.16.2 Environmental Consequences

Methodology

Agriculture

Below is a brief summary of the methodology used to analyze economic conditions from changes in agricultural production as a result of a reduction of irrigation water. For additional details on the methodology, refer to **Section TA 16.2.1**, Methodology.

Based on the SAMs and ADMs (see **Appendix C**, Shortage Allocation Model and the Alternative Distribution Model Documentation), Reclamation modeled the change in agricultural revenue from fallowed crops for each priority group by county and state in the impact analysis area due to water shortages at a variety of shortage levels across each alternative and the comparative baseline.

Forgone agricultural revenue from fallowed crops was estimated by multiplying the county-level revenue per acre by the number of acres reduced (or fallowed) for each crop. The county-level revenue was calculated based on the most recent available data on yields and prices. The number of acres reduced for each crop was modeled using an assumed fallowing order based on the crops' profitability and water use, the level of shortages and available water for each priority group by county and state, and the most recent available data on acres harvested. For data that were not available for specific crops grown in the county, estimated data were used based on statewide averages, data from nearby counties, or averages from nearby states or regions for the same or similar crops.

Irrigated crops in the analysis area that were analyzed include field crops, vegetables, and fruit and nut trees and vines, separated out into eight agricultural crop group types that would be affected by the Colorado River shortages and that made up at least approximately 1 percent of a county's harvested

acres. The eight crop groups were alfalfa, cotton, crucifer vegetables, field grains, fruit and tree nuts and vines, other hay and haylage, small grains, and small vegetables.

Impacts on economic conditions, such as jobs and income, from changes in agricultural production were analyzed using the IMPLAN input-output economic model. IMPLAN is a regional economic model that estimates how a change in one sector affects jobs, income, and spending in other parts of the economy. For example, the IMPLAN model provides annual average estimates of how a direct change in economic spending (such as through reduced agricultural revenues) would ripple through the broader economy and other industries. Prior to running the model, cost data were converted to a consistent dollar year (2025). Unless stated otherwise, monetary values are reported in the year 2025 dollars.

Recreation

This analysis evaluates how changes in reservoir elevations and river flows may affect recreational use and related economic contributions. The approach integrates visitor use data, spending information, and economic modeling tools to characterize potential changes in both the recreational experience and the regional economy.

For lake-based recreation, the analysis uses visitor statistics from the NPS and Reclamation to estimate changes in visitation levels under different hydrologic conditions. Visitor days are categorized by visitor type, including local and nonlocal trips. Each visit type is linked to an established spending profile that reflects patterns in lodging, food, transportation, recreational services, and other trip-related expenditures. Total spending estimates are then used in IMPLAN to assess potential changes in jobs, labor income, value added, and overall economic output resulting from changes in recreational use.

For river-based recreation, the analysis also evaluates net economic value, which is the value of the benefits that recreationists receive beyond what they spend directly on a trip. Consistent with the approach used in the 2024 LTEMP Final SEIS, past survey research, including that by Gaston et al. (2015), informs models that relate the willingness to pay for boating and angling experiences to the river's flow conditions. These models estimate how changes in hydrologic patterns may affect the value of specific recreational experiences in Glen Canyon and Grand Canyon.

For the action alternatives, potential changes to recreation's contributions are discussed qualitatively, based on the DMDU modeling output and conclusions related to Lake Powell and Lake Mead access to recreation and river-based recreation, as determined by river flow levels and fluctuations, as discussed in **TA 14**, Recreation.

Together, these components provide a qualitative and quantitative framework for assessing how operational changes influence recreational access, the quality of the experience, and economic contributions. Additional methodological detail, including data sources, assumptions, and model parameters, is provided in **TA 16**, Socioeconomics.

Ecosystem Services and Nonmarket Values

The analysis of ecosystem services and nonmarket values uses a qualitative framework to evaluate how changes in Colorado River operations may affect benefits that are not reflected in market transactions but that contribute to community well-being, cultural identity, and the recreational experience. These include values such as scenic quality, sense of place, ecological integrity, and cultural connections to the

river corridor. The analysis draws on scoping input, existing literature, and information from other resource sections to understand how various groups interact with and derive value from the Colorado River system. Additional details on information sources, assumptions, and community context are provided in **TA 16**, Socioeconomics.

Impact Analysis Area

Agriculture

The quantitative impact analysis was conducted for the following counties: La Paz, Maricopa, Mohave, Pima, Pinal, and Yuma Counties in Arizona; Imperial, Riverside, and San Bernardino Counties in California; and Clark County in Nevada. The impact analysis area for the qualitative discussions extends to the surrounding communities and tribal reservations.

Recreation

The analysis area is consistent with the general socioeconomic study area defined in **Section 3.1**, Introduction. This includes major recreation hubs, gateway communities, and rural areas where economies rely heavily on river- and reservoir-based recreation. Specifically, the recreation impact analysis area encompasses three primary NPS units: Lake Mead NRA, Glen Canyon NRA, and GCNP.

Ecosystem Services and Nonmarket Values

The analysis area for social and nonmarket values is the Colorado River corridor from Lake Powell to the SIB, consistent with the overall socioeconomic study area. The analysis focuses on communities within the river corridor, but it also includes communities outside of the area for whom the river holds symbolic, ecological, or recreational importance.

Assumptions

Modeling Representative Preferred Alternative Shortage Distributions

Under the Representative Preferred Alternative, two different approaches to distributing shortages are modeled, where (1) 2027-2028 modeling assumes shortage volumes up to 1.5 maf are distributed using the approach developed by the Lower Division States, and shortage volumes from 1.5 maf to 3.6 maf are distributed using the priority system, and (2) from 2029 through 2060, modeled shortage volumes are distributed using the priority system. Refer to **Section 2.4** for additional information. Some impacts are influenced by how the Representative Preferred Alternative distributes Lower Basin shortages in 2027-2028 vs. 2029-2060, and some impacts are either minimally sensitive or not sensitive to this distinction. Impacts discussion will include references to different time periods where relevant.

Agriculture

Below is a list of the key assumptions used in the analysis. For additional details on assumptions, refer to **Section TA 16.2.1**, Methodology.

- Farmers would fallow irrigated crops in response to water shortages rather than using other water sources or switching to more profitable or less water-intensive crops. The assumption that farmers would fallow rather than switch crops is based on the investments and institutional knowledge that have been made in plants, supply chains/relationships, and/or machinery that create barriers for changing crops. Reclamation understands that there could be farmers who are able to switch crops, rather than fallow; however, for the purpose of this analysis, this assumption provides a conservative estimate; if some farmers switch crops or

water sources instead, impacts would likely be less severe than discussed below. Impacts on economic conditions due to the use of groundwater to replace the estimated water shortage are discussed qualitatively.

- As discussed above, the analysis assumes that the least profitable crop would be fallowed first, analyzed for each county separately, and crops were assumed to have constant profitability per acre of land and per acre-foot of water.
- Estimated shortages in the agricultural sector are based on the SAMs and ADMs (**Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation). Shortages to individual entitlement holders are measured in terms of consumptive use for a common basis of comparison with state apportionments and volumes of total shortage. Impacts on future opportunities to expand water use due to shortages for irrigation entitlement holders who currently use less than their entitlement are discussed qualitatively.
- In most cases, the contractor, subcontractor, or entitlement holder of an allocation is shown as the entity bearing shortage. In some cases, water allocated to an entitlement holder (for example, a tribal CAP contractor) may lease its allocation to other users (for example, to a non-Indian municipality). The SAMs and ADMs do not attempt to replicate those arrangements, and they only provide approximate estimates at the level of the entitlement holder, contractor, or subcontractor. The entitlement holder, contractor, or subcontractor involved in a leasing arrangement would make specific decisions during Shortage Conditions to administer those arrangements that Reclamation cannot predict with sufficient certainty to analyze in this EIS.

Recreation

- Lake-based recreational spending per visitor trip is based on the most recent NPS Visitor Spending Profiles.
- IMPLAN results represent regional impacts, including direct, indirect, and induced economic activity associated with lake-based recreation.
- Recreational spending per trip for anglers and whitewater rafting (adjusted for inflation) would follow results from willingness-to-pay surveys (Gaston et al. 2015) with variation based on river flows.

Ecosystem Services and Nonmarket Values

- Nonmarket values are not directly quantifiable through market-based indicators; however, they can be described qualitatively based on existing studies, stakeholder input, and related resource analyses.
- Changes in nonmarket values are assumed to be closely linked to conditions evaluated in other technical appendices, such as those for recreation, population and land use, cultural resources, and visual resources.
- Changing hydrology may influence how these values are perceived, particularly where access, scenic character, or ecological conditions are affected.

Impact Indicators

Agriculture

- Change in acres of fallowed cropland
- Change in production value or revenue associated with fallowed cropland
- Change in jobs and income associated with agriculture
- Change in nonmarket values and social conditions associated with changes in agriculture

Recreation

- Changes in direct recreational visitor spending across the affected NPS units and recreation sites
- Changes in regional employment, labor income, value added, and total economic output from lake-based recreation-related activities
- Impacts on the recreational value associated with river-based boating and angling
- Impacts on commercial outfitters, concessionaires, and permittees, especially in areas dependent on rafting, boating, and guided recreation

Ecosystem Services and Nonmarket Values

- Changes in the availability or quality of recreational opportunities not captured by direct spending
- Changes in the river's existence and symbolic values due to shifts in the scenic character or ecological conditions

Issue 1: How would the anticipated water shortages affect the economic contributions and social conditions from agriculture?

Under all alternatives and the CCS Comparative Baseline, anticipated shortages would result in increases in acres of fallowed cropland and agricultural production loss, and the modeled agricultural production loss would result in impacts on the associated jobs, income, and total economic output. Additionally, under the alternatives and the CCS Comparative Baseline, water shortages would likely lead to changes in the quality and access to nonmarket values and social conditions associated with changes in agriculture (Curtis et al. 2023). These values that could be affected by water shortages include the way of life of individuals throughout the surrounding communities, how individuals perceive their sense of place, food and other resources supported by the Colorado River, access to affordable health care, and access to cultural, traditional, and spiritual practices. The magnitude of impacts on economic, nonmarket, and social conditions varies by region, irrigation and tribal entitlement holder, priority group, and the alternatives and the CCS Comparative Baseline. The discussion below provides a summary of impacts on economic, nonmarket, and social conditions across the alternatives and the CCS Comparative Baseline by state and irrigation and tribal entitlement holder. For additional details and the figures with modeling results, including results separated by priority group, refer to **Section TA 16.2.2**, Environmental Consequences, Issue 1.

On average, for non-tribal agriculture entitlement holders in Arizona, the greatest impacts on economic and social conditions from increases in fallowed lands and reductions in the market value of crops, during a maximum shortage, would occur under the Maximum Operational Flexibility Alternative (during a shortage of 4.0 maf), with an annual estimated reduction of about 1,000 jobs,

$56.5 million in labor income, and $237.7 million in total economic output. The lowest impacts on economic conditions from increases in fallowed lands and reductions in the market value of crops, during a maximum shortage, would occur under the No Action Alternative (during a shortage of 0.6 maf), for non-tribal agriculture entitlement holders in Arizona; under this alternative, there would be an annual estimated reduction of about 13 jobs, $0.6 million in labor income, and $2.8 million in total economic output. Under the Representative Preferred (2027-2028) Alternative, during a shortage of 1.5 maf, there would be a reduction of about 40 jobs, $2.0 million in labor income, and $8.9 million in total economic output[19]. Under the Representative Preferred (2029-2060) Alternative, during a maximum shortage of 3.6 maf, there would be a reduction of about 900 jobs, $50.5 million in labor income, and $210.7 million in total economic output.

For non-tribal agriculture entitlement holders in California, on average, the largest impacts on social conditions from increases in fallowed lands and reductions in the market value of crops, during a maximum shortage, would occur under the Enhanced Coordination Alternative (during a shortage of 3.0 maf). However, the biggest impacts on jobs, labor income, and economic output during a maximum shortage would occur under the Maximum Operational Flexibility Alternative, with an annual estimated reduction of about 11,000 jobs and $824.7 million in labor income, and $1.8 billion in economic output. For non-tribal agriculture entitlement holders in California, there would be no impacts on fallowed lands, the market value of crops, and economic conditions during a maximum shortage under the No Action Alternative (during a shortage of 0.6 maf) and the Basic Coordination Alternative (during a shortage of 1.5 maf). Under the Representative Preferred (2027-2028) Alternative, during a shortage of 1.5 maf, there would be a reduction of about 140 jobs, $8.5 million in labor income, and $36.9 million in total economic output. Under the Representative Preferred (2029-2060) Alternative, during a maximum shortage of 3.6 maf, there would be a reduction of about 9,000 jobs, $718.1 million in labor income, and $1.3 billion in total economic output.

For tribal agriculture entitlement holders in Arizona, during a maximum shortage, the highest level of impacts on economic and social conditions from increases in fallowed lands and reductions in the market value of crops would occur under the Maximum Operational Flexibility Alternative (during a shortage of 4.0 maf), with an annual estimated reduction of about 1,000 jobs, about $64.7 million in labor income, and $222.6 million in total economic output. The lowest impacts on economic and social conditions during a maximum shortage would occur under the No Action Alternative (during a shortage of 0.6 maf), for tribal agriculture entitlement holders in Arizona, with an annual estimated reduction of about 140 jobs, $10.7 million in labor income, and $34.8 million in total economic output. Under the Representative Preferred (2027-2028) Alternative, during a shortage of 1.5 maf, there would be a reduction of about 400 jobs, $25.2 million in labor income, and $83.3 million in total economic output. Under the Representative Preferred (2029-2060) Alternative, during a maximum shortage of 3.6 maf, there would be a reduction of about 1,000 jobs, $64.0 million in labor income, and $220.0 million in total economic output.

For California and Nevada tribal entitlement holders, the only impacts on fallowed lands, the market value of crops, and economic conditions are expected to occur under the Enhanced Coordination

[19] While the Representative Preferred (2027-2028) Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative).

Alternative and Supply Driven Alternative (LB Pro Rata approach). The greatest impacts on economic and social conditions from increases in fallowed lands and reductions in the market value of crops, during a maximum shortage, would occur under the Enhanced Coordination Alternative (during a shortage of 3.0 maf), with an annual estimated reduction of about 63 jobs, $3.9 million in labor income, and $15.9 million in total economic output for tribal entitlement holders in California; for Nevada, there would be an estimated reduction of about 13 jobs, $0.1 million in labor income, and $0.9 million in total economic output for tribal entitlement holders. There are no expected impacts on fallowed lands, the market value of crops, and economic conditions under all other alternatives and the CCS Comparative Baseline for California and Nevada tribal entitlement holders, including under the Representative Preferred Alternative.

Long-term, severe shortages could further affect entitlement holders that have unused water entitlement above their current consumptive use. Irrigation entitlement holders who currently use less than their entitlement (measured in terms of diversion, consumptive use, or both) might not immediately experience impacts on economic contributions from water shortages; however, long-term, continued shortages would limit future opportunities to expand the irrigation entitlement holders' water use, which would result in impacts on economic contributions through reduced opportunities for future developments, expansion of crop production, or additional opportunities to lease water.

If farmers and agricultural producers decide to use irrigation water from other sources—such as other surface water or groundwater sources—instead of fallowing agricultural acreages, the impacts on the economic and social conditions, discussed above, are likely to be lessened in the short term. However, in the event of long-term shortages, if the sustained demand for groundwater results in a reduction in supply from the aquifers, there would likely be increased impacts on economic and social conditions. Additionally, the reliance on more pumped groundwater to offset delivery shortages can lead to substantial additional pumping costs, particularly for electricity, which can affect economic conditions. These impacts on economic and social conditions would affect tribal and non-tribal entitlement holders in Arizona, California, and Nevada, as well as farmers and tribes who rely solely on groundwater for irrigation and domestic needs.

Issue 2: How would operational changes affect economic contributions and the value associated with lake-based and river-based recreation?

Recreation along the Colorado River is a key part of several local economies, supporting thousands of jobs and generating revenue through visitor spending. Lake-based recreation at Glen Canyon NRA and Lake Mead NRA, combined with river-based activities in GCNP, currently contribute approximately 19,000 jobs and $2.1 billion in annual economic output (Flyr and Koontz 2024). These benefits extend beyond direct spending on lodging, food, and equipment and include indirect and induced impacts throughout gateway communities. Stable reservoir elevations and predictable river flows are essential for maintaining these contributions.

Operational changes under the proposed alternatives would influence these conditions in different ways. The alternatives that maintain higher and more consistent water levels would preserve boating access, marina operations, and shoreline recreational opportunities. This stability would support continued visitation and minimize disruptions to businesses dependent on tourism. Conversely, the alternatives that result in greater variability in lake elevations and river flows would affect recreational quality and access and related levels of contributions.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) poses the greatest risk to recreation-based economies relying on economic contributions from reservoir-based recreation in Lake Powell, while the CCS Comparative Baseline and the No Action Alternative have the least robust modeled performance for supporting recreational opportunities and spending associated with Lake Mead recreation. In contrast, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in more consistent reservoir levels at Lake Powell to support recreation, and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would support the greatest level of contributions from recreation in Lake Mead.

However, under all alternatives, limited launch access and safe navigation routes at Lake Powell, along with navigation challenges in Lake Mead would continue to affect lake-based recreational opportunities and the associated spending. As a result, outfitters and concessionaires operating in these areas would face increased uncertainty, affecting employment and revenue streams under all alternatives. Research indicates that declines in lake elevation can reduce visitation by more than 25 percent, amplifying economic losses for local communities (Johnson et al. 2016). Lake Mead would experience similar constraints, with boating access severely limited during extended drought periods.

River-based recreation is also vulnerable to operational changes. Activities such as angling in Glen Canyon and whitewater rafting in Grand Canyon depend on stable flows to ensure safety and trip quality. Reduced flows shorten rafting seasons and diminish the overall experience, leading to lower recreational value and reduced demand for outfitter services and the associated hospitality sectors. The Basic Coordination Alternative would provide the most support for continued or increased economic value associated with boating and angling and the related economic contributions (see **Figure 16-13** and **Figure 16-14** in **Section TA 16.2.3**). The Enhanced Coordination Alternative would be the least robust at maintaining or exceeding the minimum desired daytime flows to support boating in Grand Canyon; it also would result in the greatest potential for a reduction in the recreational value for whitewater rafting and angling, as well as the regional economic contributions associated with these uses. Impacts would be most pronounced under dry conditions.

Economic impacts extend beyond direct visitor spending. Gateway communities, often small and rural, rely heavily on tourism-related income to sustain local businesses and municipal services. When lake levels drop or river flows decline, these communities experience cascading impacts, including reduced tax revenues and job losses in sectors such as lodging, food service, and transportation. The magnitude of these impacts would depend on the frequency and duration of low-elevation conditions, which would vary significantly across the alternatives.

Maintaining reservoir elevations and river flows within ranges that support recreation is critical for protecting the economic contributions and community well-being. For detailed analysis, including supporting data and tables, see the technical appendix sections for socioeconomics and recreation.

Issue 3: How would anticipated water shortages and changes in water levels in reservoirs and river segments affect access and the quality of nonmarket values?

Nonmarket values, such as scenic quality, opportunities for solitude, and cultural connections, are central to the Colorado River system and its surrounding landscapes. These values are not reflected in direct economic measures but are essential to visitor experiences and the cultural identity of tribes and gateway communities. Stable reservoir elevations and predictable river flows help maintain visual

integrity, access to culturally significant sites, and the immersive qualities that define national parks and recreation areas (Flyr and Koontz 2024).

The alternatives that maintain relatively stable reservoir levels and minimize flow variability provide stronger protection for these intangible benefits. Under these scenarios, boating and rafting experiences retain their quality, the scenic character remains intact, and opportunities for solitude and reflection are disrupted less. These conditions also support traditional practices for tribes, which often depend on predictable water levels and access points for cultural and spiritual activities. There may be exceptions to this generalization; for example, alternatives which provide better support for river-based recreation and associated values may result in less preferable outcomes for reservoir-based recreation and vice-versa.

During wet hydrologic conditions, the range of alternatives would generally produce conditions where lake levels and flows along the Colorado River would result in minimal impacts on nonmarket values, although this varies by resource. For example, nonmarket values such as scenic integrity, solitude, and cultural connections to the river corridor would be maintained at a level similar to current conditions. Similarly, ecological services, including riparian habitat and wildlife viewing opportunities, remain similar to current conditions and cultural landscapes would retain the factors which are associated with nonmarket values. Recreational experiences for boating, angling, and rafting, however, may be impacted under all alternatives in their quality and support for sense of place for gateway communities and visitor, as modeling indicates that periods of reservoir elevations below thresholds for recreation facility access and navigation would be more likely than that under historic conditions.

As conditions become drier, the No Action Alternative and CCS Comparative Baseline would result in the most modeled futures where impacts could occur to resources with nonmarket values. For example, nonmarket values for recreation and ecosystem services could be reduced in instances of prolonged drought, which could reduce shoreline aesthetics and diminish the opportunities for solitude at Lake Powell and Lake Mead over time. Extended low-flow periods could also impact river-based experiences in Grand Canyon due to changes in setting which could impact perceived naturalness. Cultural and spiritual values tied to iconic landscapes and cultural artifacts could also be affected in low-hydrologic flow periods. Ecological services such as riparian habitat stability may decline, influencing nonuse values related to wildlife and vegetation communities.

Under drier conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would be more robust in terms of the support for nonmarket values; particularly for values associated with Lake Powell. Reservoir levels which are maintained at thresholds that support access for boating and camping in more modeled futures, support experiential benefits and cultural connections (see **TA 11**, Cultural Resources). The quality of river-based recreation is expected to remain high, due to increased stability with flow-dependent activities (see **TA 14**, Recreation); however, a lower average flow may impact some values. However, the Maximum Operational Flexibility, Enhanced Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives include the largest potential shortages to minimize the number of future conditions where dead pool could be reached based on DMDU modeling as described in **TA 4**, Water Deliveries.

More frequent low-elevation conditions would be introduced in the Basic Coordination Alternative, which could noticeably affect the nonmarket values tied to lake-based recreation and scenic quality (see **TA 14**, Recreation) although at a reduced level compared with the No Action Alternative and the CCS Comparative Baseline. Reduced reservoir levels may expose previously submerged areas, altering visual character and diminishing the opportunities for solitude. River-based recreation could experience flow variability that affects trip quality and angling success (see **TA 3**, Hydrologic Resources); however, higher average flows may support some river-based values.

Outcomes produced by the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) vary depending on the hydrology and location. In wet years, the nonmarket values supported would remain similar to those under the CCS Comparative Baseline; however, in dry sequences, reduced reservoir elevations and altered flow regimes would diminish the scenic quality and access for boating and angling at Lake Powell (see **TA 14**, Recreation). At Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust at maintaining reservoir levels that support nonmarket values. River-based recreation would experience moderate variability in trip quality, while ecosystem services and the associated nonuse values would fluctuate with water availability (see **TA 8**, Biological Resources – Fish and Other Aquatic Species). Similar to the Basic Coordination Alternative, however, higher average flows may support some river-based values.

Under the Representative Preferred Alternative, as under all alternatives, non-market values associated with recreation would continue to be impacted, by reduced access to recreation facilities and navigation challenges in Lake Powell and Lake Mead. Modeled results show reduced low-elevation outcomes compared to more vulnerable alternatives, but vulnerability remains under drier future hydrologic conditions (see **TA 3,** Hydrologic Resources). The Representative Preferred Alternative generally performs in the middle of the range of alternatives for both Lake Powell and Lake Mead elevations as well as river flow, showing moderate robustness in terms of overall support for recreation associated benefits (**TA 14**, Recreation). Overall, this alternative would provide moderate protection for riverine habitat to support cultural values (see **TA 13**, Tribal Resources).

Summary Comparison of Alternatives

The lowest impacts on economic and social conditions from reductions in agricultural production and increases in fallowed lands due to shortages in irrigation water, across all alternatives, states, and tribal and non-tribal irrigation entitlement holders, would occur under the No Action Alternative due to the low maximum shortage of 0.6 maf; however, across the action alternatives, impacts on economic and social conditions from changes in agriculture would vary across irrigation entitlement groups, based on the maximum shortage levels and water shortage distribution methods. For all irrigation entitlement holders except Arizona tribal, impacts on the economic and social conditions from agricultural activity would tend to be lower under the alternatives with a low maximum shortage level and priority-based shortage distribution methods, and impacts would tend to be higher under the alternatives with a high maximum shortage level or pro rata-based shortage distribution methods, compared with other action alternatives.

However, for Arizona tribal entitlement holders, lower impacts on economic and social conditions due to reductions in agricultural production would occur under alternatives with pro rata shortage distribution methods, and higher impacts occur under the alternatives with priority shortage distribution methods, compared with other action alternatives. Overall, the alternatives demonstrate a

trade-off between shortage distributions across irrigation entitlement holders, flexibility in the maximum allowable shortage implementation, and the ability to support stable agricultural production and social well-being.

Operational changes under the proposed alternatives would influence these conditions in different ways. The alternatives that maintain more consistent reservoir levels would preserve boating access, marina operations, and shoreline recreational opportunities. This stability would support continued visitation and minimize disruptions to businesses dependent on tourism. Conversely, the alternatives that result in greater variability in lake elevations and river flows would affect the recreational quality and access and the related levels of contributions. Similarly, the alternatives that maintain consistent and adequate river flow below Glen Canyon Dam would offer continued support for recreational experiences with high value for whitewater boating and angling, and for the related spending in gateway communities and the regional economy.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) poses the greatest risk to recreation-based economies relying on economic contributions from reservoir-based recreation in Lake Powell, while the CCS Comparative Baseline and the No Action Alternative have the least robust modeled performance for supporting recreational opportunities and spending associated with Lake Mead recreation. In contrast, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in more consistent reservoir levels at Lake Powell to support recreation, and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would support the greatest level of contributions from recreation in Lake Mead. However, under all alternatives, access to launch facilities and safe navigation routes for Lake Powell and navigational challenges in Lake Mead would continue to impact lake-based recreational opportunities and the associated spending.

River-based recreation is also vulnerable to operational changes. Activities such as angling in Glen Canyon and whitewater rafting in Grand Canyon depend on stable flows to ensure safety and trip quality. Reduced flows shorten rafting seasons and diminish the overall experience, leading to lower demand for outfitter services and the associated hospitality sectors. While the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would offer more consistent flows than the other alternatives, it would not fully mitigate risks. The Enhanced Coordination Alternative would be the least robust at maintaining or exceeding the minimum desired daytime flows to support boating in Grand Canyon; it would also result in the greatest potential for a reduction in the recreational value for whitewater rafting and the associated regional economic contributions associated with these uses.

Nonmarket values, such as scenic quality, opportunities for solitude, and cultural connections, are central to the Colorado River system and its surrounding landscapes. In general, stable reservoir elevations and predictable river flows support these factors and the value for locals and visitors. As a result, the alternatives that maintain relatively stable reservoir levels and minimize flow variability would provide stronger protection for these intangible benefits. During wet hydrologic conditions, the range of alternatives would generally produce conditions where lake levels and flows along the Colorado River would result in minimal impacts on nonmarket values. As conditions become drier, however, the No Action Alternative and CCS Comparative Baseline would result in greater variability in reservoir elevations and river flows. This would result in the potential to expose barren drawdown zones, alter shoreline appearance, and reduce the aesthetic values tied to natural landscapes. Variability in flows can also affect the timing and accessibility of cultural practices, creating challenges for

maintaining traditional uses. Visitors seeking a consistent wilderness experience may perceive degraded conditions when confronted with stark elevation changes or shortened seasons, which can influence perceptions of resource stewardship and long-term visitation patterns.

Under drier conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would generally be more robust at maintaining key reservoir and river flow thresholds that support the resources with associated nonmarket values. On the other hand, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would result in the most robust preservation of Lake Mead's reservoir levels at thresholds to support resources with nonmarket values.

3.17 Population and Land Use

3.17.1 Affected Environment

This section explores the baseline conditions and potential impacts from different Colorado River operational strategies on analysis area population dynamics and land use changes, with a focus on potential changes in developed lands and lands used for irrigated agriculture.

The full detailed analysis of population and land use can be reviewed in **TA 17**, Population and Land Use. **Sections TA 17.1.1**, **17.1.4**, and **17.1.6** provide comprehensive baseline information to characterize the existing setting and trends related to population, general landownership and management, and developed land patterns. Information is also provided for municipal water, which supports developed land use. Data are provided related to historical agricultural land use to support the discussion of irrigated agriculture.

Due to the influence of municipal water availability on developed lands, the impacts analysis examines changes to water availability for municipal supply and the related impacts on population and land use changes. **Sections TA 17.1.2** and **17.1.3** provide detailed information on industrial and municipal water uses and study area municipalities.

Due to the influence of irrigation water availability on agricultural land use, the impacts analysis examines changes to irrigation water availability and related impacts on acres of lands in agriculture. **Section TA 17.1.5** provides detailed information on agricultural land use within the study area, including irrigated acres of harvested cropland and the percentage of irrigated water from surface water resources.

The analysis area for the population and land-use section is separated by state and is described in **Section 3.17.2**. For a detailed description of the analysis area and rationale for selecting the Arizona, California, Nevada and Utah Counties, refer to **TA 17.1.** A high-level overview of key trends for population and land use is provided below.

Population

Population is one driver of demand for consumptive water use, particularly for municipal water. Communities throughout much of the western U.S. have followed trends of increasing populations over the past decade. In the analysis areas, the population growth rate has generally been positive or

stable. **Section TA 17.1.1** provides the historical and projected population for the Arizona, California, Nevada, and Utah analysis area counties.

Population trends varied across the analysis areas over the past decade. Arizona experienced population growth, particularly in urban and suburban settings, due in part to relatively affordable housing and expanding job opportunities in emerging sectors. In Nevada, population growth was concentrated in Clark County and the Las Vegas metropolitan area, where tourism, hospitality, and related services continue to support population growth. California experienced more varied population trends, with urban centers experiencing steady growth while certain rural areas experienced slower growth or population declines.

In Arizona, population growth in some counties has reached over 30 percent, and Nevada's urban centers have seen substantial increases that exacerbate water demand and place stress on existing resource systems. California, with its large and diverse population, faces the challenge of balancing high urban density with water conservation measures, ensuring that residential and industrial growth complies with sustainable water use practices. Projections across the three states indicate continued growth that will necessitate further investments in water infrastructure and resources to meet municipal demands. More detailed information is provided in **Section TA 17.1.1**.

Population growth can increase the demand for water for domestic, agricultural, and industrial use and increase pressure on existing water sources. Studies have shown that population growth can be a dominant driver of long-term municipal water demand (Liu et al. 2025). Insufficient water supply can constrain population growth and development by limiting an area's capacity to support residents.

Industrial and Municipal (Domestic) Water Uses and Trends

The Colorado River is an important water source serving municipalities, industries, and agricultural operations in Arizona, Nevada, and California. **Section TA 17.1.2** provides a detailed overview of industrial and municipal (domestic)[20] water supply, demand, and use trends within the U.S. and the Lower Basin. **Section TA 17.1.3** provides information on the municipalities within Arizona, California, and Nevada with the potential to be affected by changes in domestic water availability. Municipal water systems in these regions face growing pressures from population growth, climate trends, and uncertainties in future water availability, demand, and technological or policy adoption (Liu et al. 2025). Water management strategies—including conservation measures, demand-side management, and technology upgrades—have been implemented to mitigate these pressures and maintain system reliability.

Although existing and ongoing municipal water management strategies do not change domestic water entitlement amounts, they illustrate how municipal systems have adapted—and may continue to adapt—to evolving water supply and demand conditions. This context is important for understanding how communities in the region would respond to variability in water availability under different future conditions. Across the analysis areas, municipal providers employ a range of adaptation measures to manage supply variability and shortages. In Arizona, measures commonly include demand management and conservation; increased reliance on groundwater and stored supplies, including recharge and banking, where available; reclaimed water for non-potable demands; and system

[20] Domestic water use includes the use of water for "household, stock, municipal, mining, milling, industrial, and other like purposes" (1922 Colorado River Compact, section II(h)).

interconnections or operational changes. In California, measures commonly include conservation; recycled water expansion; stormwater capture and local recharge; groundwater management; interties and transfers, where available; and targeted supply or treatment improvements. In Nevada (Clark County), measures commonly include incentives to reduce outdoor water use, extensive reuse and return-flow management, and storage and exchange arrangements coupled with operational and infrastructure modifications to improve drought resilience. Many measures involve substantial capital costs and multiyear implementation timelines and may be constrained by legal or contractual availability, physical system capacity, water quality and treatment requirements, permitting, energy demands, and environmental considerations, which can limit feasibility or timing for some communities.

The availability of and access to domestic water can influence population dynamics and land use patterns in the region (**Section TA 17.1.2**). Peer-reviewed studies have documented the relationships between population growth, land use patterns, and domestic water delivery. Urban sprawl, characterized by low-density development and increased impervious surfaces, has been shown to elevate per capita water demand through higher outdoor water use (Heidari et al. 2021). In contrast, high-density development often reduces water use per capita and can lessen the frequency and severity of water shortages. Rapid urbanization and population growth can also increase pressure on existing water infrastructure, creating challenges in maintaining consistent domestic water delivery.

Municipal water demand within the analysis area depends on more than population or economic growth and can reflect long-term trends in conservation, efficiency, reuse, land-use patterns, climate, and provider policies. Many municipal providers in the Lower Basin have implemented demand management programs and operational practices that have reduced per-capita use over time, such that total municipal demand may remain stable or grow more slowly than population in some communities. Conversely, the magnitude of realized conservation and the remaining potential for additional cost-effective savings vary by provider due to differences in existing program maturity, customer mix, climate, built environment, system losses, regulatory constraints, and local supply portfolios.

Municipal planning and development within the Lower Basin counties in the analysis area rely on assumptions about the reliability, timing, and quality of water supplies used to serve existing and future demands. Within the analysis area counties, local governments and water providers typically integrate water-supply expectations into general plans, zoning and subdivision decisions, capital improvement programs, and long-range utility master planning. These assumptions inform the sizing and sequencing of major infrastructure (e.g., treatment, conveyance, storage, and pressure zones), operational and drought contingency planning, and the ability to maintain service standards under variable hydrologic conditions. Many providers in these counties manage portfolio supplies that may include Colorado River–derived deliveries alongside local surface water, groundwater, conservation, reuse, and interconnections. Because of this, domestic water reliability depends not only on annual volume but also operational availability during peak demand, drought response triggers, and constraints associated with treatment and regulatory compliance. Accordingly, changes in the reliability of Colorado River supplies can be relevant to municipal planning baselines and the context for evaluating potential effects related to domestic water shortages discussed in **Section 3.17.2** (**Section TA 17.2.2** for more information).

Water supply has influenced land use and development within the analysis area. Arizona Department of Water Resources' (ADWR) Assured and Adequate Water Supply programs provide a concrete example of how water availability can constrain development. While not directly tied only to Colorado River water, The ADWR's Assured and Adequate Water Supply programs require developers to demonstrate assured or adequate water supplies before proceeding with new projects. This context provides one example of how planning assumptions for water supply relate to residential and commercial development and helps frame how communities might respond to changes in water availability under future conditions.

Domestic water supply reliability also supports baseline employment and community functions across the socioeconomic analysis area. **TA 16**, Socioeconomics, **Section TA 16.1.2** provides baseline employment by sector for the Arizona, California, Nevada, and Utah counties included in the socioeconomic analysis area for 2010 and 2022 (see **Tables TA 16-1, 16-2, 16-6, 16-7, 16-11**, and **16-14**). These tables provide context for the composition of employment in the analysis area, including sectors that typically rely on continuous municipal water service to support day-to-day operations and public services. Examples of these sectors include but are not limited to information; healthcare and social assistance; retail trade; real estate; arts, entertainment, and recreation; construction; finance and insurance; manufacturing; professional, scientific and technical services; state and local government; and accommodation and food services. While county-level employment data do not distinguish among the water sources supporting certain sectors and associated economic activity and public services, the sector employment helps frame domestic water supply, demand, and use trends in the counties included in the analysis area.

In models of projected water yield and demand in the western U.S. to 2070, data indicate that demands for municipal water are increasing across the socioeconomic analysis area, while projected water availability is decreasing (see, for example, Warziniack and Brown 2019). While this trend is seen throughout the western U.S., the Colorado River region has the largest percentage increases in projected domestic water use and the greatest percentage decreases in projected water yield from all sources, including Colorado River water (Warziniack and Brown 2019).

Study Area Municipalities

The analysis area is informed by the SAMs and includes the counties represented in the SAMs. Further, the Arizona, California, and Nevada municipalities with potential to be affected by the alternatives are described in detail in **Section TA 17.1.3**. and include those represented in the SAMs.

Land Use

This section describes existing land use conditions along the mainstream Colorado River from Glen Canyon Dam to the U.S.–Mexico border. Land use includes recreation, agriculture, tribal land use, conservation and habitat management, residential and urban development, and utility and infrastructure corridors.

Landownership along the Colorado River is highly variable and includes federal (NPS, BLM, FWS, and Reclamation), tribal, state, and private lands. Federal agencies manage much of the land in the upper and middle portions of the river corridor, particularly in areas surrounding Glen Canyon NRA, GCNP, Lake Mead NRA, and multiple NWRs. Tribal lands are prominent in both Arizona and

California. State and private lands are more common in the Lower Basin, especially in urban areas like Bullhead City and Yuma and along agricultural corridors in Arizona and California.

Developed land uses occur in concentrated areas where communities and infrastructure directly rely on the Colorado River. These include recreation sites, marinas, campgrounds, roadways, water delivery systems, hydropower infrastructure, and municipal areas. While most of the corridor remains undeveloped, developed areas have expanded since the early 2000s in several locations due to population growth, recreational demand, and infrastructure upgrades. Agricultural lands are also a major land use along the river's lower reaches, particularly in western Arizona and southeastern California, where irrigated farming depends heavily on surface water deliveries.

Reservoir elevations and river flow conditions strongly influence how land near the river is used and managed. Declining water levels at Lake Powell and Lake Mead have resulted in increased shoreline exposure, changes in recreational access points, and new management needs for erosion control, sediment exposure, and public safety. These hydrologic shifts also affect agricultural land use by altering water availability for irrigation, which can contribute to fallowing or shifts to less water-intensive crops in some areas.

Agricultural Land Use

Agriculture is a major land use along the lower Colorado River, particularly in western Arizona and southeastern California, where irrigated farming relies heavily on surface water deliveries. Key agricultural areas include Yuma, La Paz, and Mohave Counties in Arizona and Imperial and Riverside Counties in California. These regions support extensive production of food, feed, and fiber crops and represent some of the most productive irrigated farmland in the country. Western Arizona counties such as Pinal, Maricopa, and Pima also contain irrigated agricultural lands, although these areas have experienced reductions in irrigated acreage over time due to water availability constraints. Trends in county-level cropland data show shifts in harvested and irrigated acreage across the region, reflecting long-term drought, changes in water deliveries, and adaptation by agricultural producers (Dieter et al. 2018; Presson and Eden 2023; USDA NASS 2024). More detailed information on the location and extent of irrigated agricultural lands is provided in the technical appendix.

3.17.2 Environmental Consequences

Methodology

The analysis of population and land use impacts evaluates a) how operational changes and changes to domestic water delivery could affect overall population and land use patterns, including developed lands for residential and commercial uses, and b) how operational changes and changes to irrigation water could affect lands used for irrigated agriculture.

To analyze how operational changes may affect population and land use patterns (Issue 1), the DMDU analysis was used. The DMDU analysis of domestic water impacts used modeled shortages to domestic users provided by the SAMs and ADMs[21] and proceeded in two main steps. First, domestic priorities were grouped: Arizona CAP non-Indian agriculture [NIA]-A and NIA-B (Group 1), Arizona

[21] There are three unique SAMs and five ADMs to capture the nuances of the alternatives and sensitivity analyses; these are further explained in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

CAP M&I and Priority 4(i) (Group 2), Arizona Priorities 2 and 3 (Group 4), Arizona PPR (Group 5), California Priority 4 (Group 6), California PPR (Group 7), Nevada Priority 8 (Group 8), Nevada Priorities 1–7 (Group 9) to capture variation in modeled shortage by priority across the SAMs. Second, the modeled domestic shortage was analyzed for each priority group to determine the shortage levels at which the group's average percentage shortage equaled approximately 20, 40, 60, 70, 80, or 100 percent of its total entitlement. These thresholds were applied within the DMDU framework to develop **Figures TA-17-2** through **TA-17-9**, which depict the percentage of modeled futures where each priority group maintains the specified fraction of normal water deliveries in 90 percent of years across the action alternatives. For the purpose of this analysis, "normal delivery" is defined as a full Colorado River or CAP entitlement supply. The figures provide a direct comparison of domestic water impacts across priority groups and the alternatives. Additional information on the DMDU robustness and vulnerability concepts used to interpret these results is provided in **Appendix E** (DMDU Overview and Approach). Modeling assumptions and shortage allocation frameworks that inform domestic delivery outcomes are documented in **TA 4**, Water Deliveries. While this section focuses on domestic shortage impacts on priority groups, domestic shortage impacts for each entitlement can be found in **Appendix C**.

To analyze how operational changes may affect agricultural land use (Issue 2), this analysis relied on modeled shortages to irrigation users at the state level, produced by the SAMs. For more detailed information on the SAMs and consumptive impacts on irrigation users, see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation. For more information on water deliveries and shortage impacts, including those for irrigation, refer to **TA 4**, Water Deliveries.

Impact Analysis Area

The analysis area for the population and land use section is separated by state and is the same for both population and land use issues. The impact analysis area is defined by those counties that may be affected by management direction that could result in water shortages to domestic and irrigation users. As described above, both issue statements rely on the SAMs. As a result, the analysis area is informed by the SAMs and includes the counties represented in the SAMs. The Arizona analysis area consists of Apache, Coconino, Gila, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, and Yuma Counties. These include counties that are directly adjacent to Lake Powell, Lake Mead, or the Colorado River and counties in which shortages would likely occur. The California analysis area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. These counties were selected because they are either directly adjacent to the lower Colorado River, or they are within the MWD service area. Although Ventura County is also in the MWD service area, it does not receive any water from the Colorado River; therefore, it is not included in the analysis area. The Nevada analysis area consists of Clark County. The Nevada analysis area was limited to Clark County because Clark County is adjacent to Lake Mead and encompasses SNWA's service area and other individual water providers. Shortages in Nevada would be limited to SNWA's service area.

Across the states, these counties were selected for inclusion in the analysis area because they represent the counties in which there is potential for direct impacts from shortages, based on modeled domestic (municipal) delivery outcomes and the service areas of major municipal providers. Secondary impacts could also occur in adjacent counties, across states as a whole, in adjacent states, and/or at the national scale (e.g., through economic linkages and supply chains). However, due to analytical constraints and

the focus of this analysis on a DMDU-informed assessment of modeled domestic shortage outcomes for selected municipal providers, the population and land use analysis focuses on direct impacts within the counties that correspond to municipal service areas and areas where delivery reductions could most directly influence land-use-related conditions.

This approach is consistent with the socioeconomic framing (**TA 16**, Socioeconomics), which defines analysis areas using counties adjacent to reservoirs and the Colorado River and counties containing major municipal service areas that receive water from the Colorado River (e.g., in California, counties within the MWD of Southern California service area that receive Colorado River water).

Assumptions

- Colorado River operations do not directly control population change, but they may indirectly influence migration patterns.
- Local socioeconomic conditions and demographic trends may also be influenced by factors outside river operations, such as housing costs, infrastructure investment, local attitudes towards water conservation, and regional employment patterns.
- In most cases, the contractor, subcontractor, or entitlement holder of an allocation is shown as the entity bearing shortage. In some cases, water allocated to an entitlement holder (for example, a tribal CAP contractor) may lease its allocation to other users (for example, to a non-Indian municipality). The SAMs and ADMs do not attempt to replicate those arrangements, and they only provide approximate estimates at the level of the entitlement holder, contractor, or subcontractor. The entitlement holder, contractor, or subcontractor to the leasing arrangements would have specific decisions to make during Shortage Conditions to administer those arrangements that Reclamation cannot predict with sufficient certainty to analyze in this EIS.
- Under the Representative Preferred Alternative, two different approaches to distributing shortages are modeled, where (1) 2027-2028 modeling assumes shortage volumes up to 1.5 maf are distributed using the approach developed by the Lower Division States, and shortage volumes from 1.5 maf to 3.6 maf are distributed using the priority system, and (2) from 2029 through 2060, modeled shortage volumes are distributed using the priority system. Refer to **Section 2.4** for additional information. Some impacts are influenced by how the Representative Preferred Alternative distributes Lower Basin shortages in 2027-2028 vs. 2029-2060, and some impacts are either minimally sensitive or not sensitive to this distinction. Impacts discussion will include references to different time periods where relevant.
- Impacts under the Preferred Alternative may be different from what is shown for the Representative Preferred Alternative, as this alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**. As a result, the potential for fallowing, crop switching, and other associated long-term land-use patterns in any given area may vary and impacts may be mitigated in part by specific operating guidelines.

Impact Indicators

- Shortage to domestic water users
- Acres of developed land within the analysis areas and the potential for changes based on municipal water availability
- Acres of irrigated agricultural land within the analysis areas and the potential for changes based on agricultural water availability

Issue 1: How would operational changes affect population and developed land use patterns?

This issue examines how modeled changes in domestic (municipal) delivery reliability may influence population and developed land use patterns in communities that rely on Colorado River water for municipal uses. While Colorado River operations do not directly determine population movement or developed land use patterns, long-term changes in water availability and recreational access may influence migration patterns and developed land patterns. This issue statement is analyzed by first synthesizing the DMDU results presented in **TA 17**, Population and Land Use, and then by assessing how domestic water delivery impacts would impact population and developed land use patterns. Modeled domestic (municipal) delivery outcomes are used to understand how reduced reliability may constrain population- and land-use-related conditions, including residential and commercial development, existing communities, and essential services. The DMDU results are interpreted as indicators of potential exposure to domestic shortage and associated impacts, not as direct forecasts of county-level population change, local economic output, or sector-specific impacts. Additional detail on the modeling assumptions and domestic delivery results is provided in **TA 17,** Population and Land Use, **TA 4,** Water Deliveries, **Appendix C, and Appendix E.**

Population is not treated as a direct proxy for consumptive use because conservation, reuse, and local policy can affect per-capita water use. Similarly, municipal-scale economic impacts are discussed qualitatively because comparable economic, utility finance, and sector-specific data are not uniformly available across municipal providers and service areas. **TA 16**, Socioeconomics, provides baseline socioeconomic context, including employment by sector, and **TA 17**, Population and Land Use, uses that context to discuss qualitative pathways by which reduced domestic delivery reliability may affect communities and developed land use.

Figure TA 17-2 through **Figure TA 17-9** in **TA 17**, Population and Land Use, display potential impacts on domestic water deliveries by presenting the percentage of normal domestic water deliveries that can be achieved across a range of modeled futures. Each figure illustrates the percentage of normal domestic water deliveries achieved in 90 percent of years over a 34-year modeling period, representing varying percentages of potential future scenarios for each priority group. The metric of 90 percent of years was selected for this analysis, rather than 100 percent of years, because it better displays variation between the alternatives. For each figure, the rows represent different performance thresholds, as percentages of normal delivery. Higher rows indicate a higher volume of delivery (closer to normal conditions) and are therefore challenging to achieve across a large percentage of potential futures, while lower rows represent lower levels of delivery that are easier to achieve because they allow for more frequent modeled shortages to domestic water delivery. For this analysis, greater than 80 percent of normal delivery in 90 percent of years was selected as the preferred minimum performance level. This row was highlighted because it represents the performance level closest to

normal domestic water delivery of the thresholds displayed in the figures, while also representing the earliest point at which differences among alternatives begin to emerge in the DMDU results. In other words, the greater than 80 percent row reflects the least amount of modeled shortage to domestic water users displayed in the figures and is the first row where shortages begin to manifest across alternatives.

In addition, each figure includes a bottom row that shows futures with dead pool–related reductions. These occur when Lake Mead lacks sufficient water to meet downstream demands or when Hoover Dam infrastructure limitations force releases below the required volume, typically when the lake approaches dead pool (895 feet) or even earlier (up to 950 feet). Although this analysis does not address the allocation of reductions related to dead pool, displaying these figures provides important context on the robustness of the alternatives.

Figure TA 17-2 through **Figure TA 17-9** in **TA 17**, Population and Land Use, do not capture individual years within the modeling period, however, they are modeled. The modeling assumptions for the Representative Preferred Alternative in the first two years (2027–2028) are described in **Chapter 2** and the shortages are distributed via LB priority. Therefore, up to 1.5 maf of shortage, in the first two years, impacts to Arizona CAP NIA-A and NIA-B; CAP Indian, M&I, and 4(i); and Priorities 2 and 3; California Priority 4 entitlements; and Nevada Priority 8 (including Balance and Surplus) entitlements, would be more similar to the Supply Driven Alternative (LB Priority Approach). Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage). The results for the Representative Preferred Alternative in 2029–2036, in which Priority distribution is applied, would result in more shortage impacts on Arizona junior entitlements.

The alternatives with greater robustness would likely result in fewer potential indirect impacts on population growth and developed land. Greater robustness corresponds to a higher percentage of futures in which domestic water delivery remains consistent with normal conditions and shortages occur less frequently. In contrast, less robust alternatives are more susceptible to reductions in domestic water availability because modeled shortages occur more frequently or the volume of shortage is higher. These shortages could manifest as reduced water deliveries, delivery restrictions, or the need for additional conservation measures, which could in turn limit the capacity to meet domestic water demand. A more robust alternative would therefore help ensure that domestic water supplies remain reliable to support existing populations and accommodate anticipated future growth, thereby minimizing potential secondary impacts on development patterns and land use. More detailed information on the nature and type of impacts associated with reductions in municipal delivery reliability is provided in **TA 17.2.2** and **TA 17.2.3**. The SAMs used to inform the DMDU analysis do not incorporate water management measures, such as conservation programs, or demand-reduction strategies. These measures do not change entitlement amounts or shortages; however, as noted in the affected environment section, conservation programs and other management strategies can influence domestic water demand and help mitigate the operational pressures associated with shortages, uncertain supply, and population growth. The potential impacts on domestic water supply for the Lower Division States would also depend in part on existing and future management strategies and conservation measures implemented by the states, local water providers, and individual users. Potential impacts would also depend on other external factors such as environmental and economic conditions.

Communities and municipal providers may respond to shortages through a range of adaptation measures, which could include increased conservation and demand management, use of existing storage or water banking arrangements where available, investments in infrastructure (e.g., treatment upgrades, reuse, interconnections), operational changes, or pursuit of alternative supplies and agreements. The feasibility, timing, and effectiveness of these measures would vary by location and provider, and may be constrained by physical and geographic availability of replacement water, jurisdictional and legal limitations (including state-law and contractual considerations), the time required for planning, permitting, financing, and construction, and constraints related to existing infrastructure configurations and prior investments. Adaptation measures may also involve direct and indirect economic costs to providers and ratepayers, and may require tradeoffs among objectives under different future conditions. Because the DMDU framework tests many uncertain futures, these uncertainties and constraints should be considered when interpreting robustness results and evaluating the extent to which an alternative can reduce both direct delivery impacts and potential secondary effects on development patterns and land use.

Table ES-7, Summary of Potential Effects, Population and Lands, in the **Executive Summary** provides an overview of impacts on population, lands, and domestic water by alternative based on the DMDU figures discussed in detail in **TA 17**, Population and Land Use. The table demonstrates how the different alternatives perform in terms of the percentage of normal delivery in potential futures. The table with a summary of effects on the population and lands includes two performance indicators: greater than 80 percent of normal delivery and greater than 60 percent of normal delivery in 90 percent of modeled futures, across the full modeling period. The table displays how each alternative performs for these two performance indicators, by priority group. The performance indicators illustrate how each alternative performs in maintaining domestic water deliveries under a wide range of uncertain future conditions. The alternatives that would achieve greater than 80 percent of normal delivery in 90 percent of years demonstrate strong robustness, indicating that domestic deliveries would remain near normal levels across most modeled futures. These alternatives would result in fewer and less severe shortages, which would provide greater reliability for domestic water users. This performance indicator is difficult to achieve under many alternatives.

To show further variation across the alternatives, **Table ES-7**, Summary of Potential Effects, Population and Lands, in the **Executive Summary** includes greater than 60 percent of normal delivery in 90 percent of years. The alternatives that only meet the greater-than-60-percent-of-normal-delivery-in-90-percent-of-years threshold demonstrate lower robustness. Under these conditions, more frequent domestic delivery reductions or shortages could occur in modeled futures, particularly for junior priority groups. Such outcomes could increase the likelihood of secondary socioeconomic impacts, including constraints on growth or secondary changes in land development patterns.

As described in **Section TA 17.1**, Affected Environment, and **Section 3.1**, Introduction, above, peer-reviewed studies document that domestic water availability significantly influences population dynamics and land use. **Section TA 17.2.3**, DMDU Analysis Summary, provides a detailed overview of potential impacts on domestic water and the associated impacts on population and land use patterns for Arizona, Nevada, and California. Key summaries are also provided below.

Arizona: Across the first decade of the modeling period, the CCS Comparative Baseline and No Action, Basic Coordination, and Supply Driven (LB Priority Approach) Alternatives would result in

similar impacts on domestic water supply for Arizona PPR and Arizona Priorities 2 and 3, with greater than 80 percent of normal delivery in 100 percent of potential futures. In other words, there would be no domestic shortage impacts for Arizona PPR and Priorities 2 and 3 under these alternatives. However, potential impacts do vary under the other action alternative for these two priority groups. Under the Maximum Operational Flexibility and Representative Preferred Alternatives, over 80 percent of normal delivery to Arizona Priorities 2 and 3, occurs in 26 percent and 57 percent of potential futures across the first decade of the modeling period, respectively.

In contrast, for Arizona CAP NIA-A, CAP NIA-B, CAP Indian, M&I, and 4i priorities, no alternative achieves the preferred minimum performance level of over 80 percent of normal delivery in 90 percent of years across the first decade of the modeling period. Further, under the Basic Coordination, Enhanced Coordination, and Representative Preferred Alternatives, there are no potential futures in which Arizona CAP NIA-A, CAP NIA-B, CAP Indian, M&I, and 4(i)) priority groups receive any percentage of normal domestic water delivery. Under these less robust alternatives, there is a higher frequency of shortage and no potential futures in which normal domestic delivery to these priorities occurs. A higher frequency of shortages and fewer potential futures with normal domestic delivery to these junior priorities could result in potential impacts on municipalities and communities that rely on domestic water delivery under these entitlements. Should shortages result in a reduction or elimination of legal access to municipal water, widespread impacts on social and economic conditions may also be possible. Further, the shortage distributions applied under these alternatives could result in the complete loss of domestic water for these users. However, the Enhanced Coordination and Supply Driven (LB Pro Rata Approach) Alternatives allow for over 60 percent of normal delivery in 100 percent of modeled futures for these priority groups, demonstrating its robustness compared with the other alternatives.

When considering all Arizona priority groups, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives generally demonstrate the most robust performance for domestic water entitlements, based on maintaining greater than 60 percent of normal delivery in at least 90 percent of years across the full modeling period, for the greatest number of users. Compared with the CCS Comparative Baseline and No Action Alternative, under these alternatives 60 percent or more of normal domestic water delivery occurs across the largest percentage of potential futures and for the greatest number of priority groups. While this approach maximizes delivery reliability for more users overall, it involves a trade-off: Some senior entitlements would experience delivery reductions that would not occur under priority distribution, whereas more junior entitlements may continue to receive near-normal deliveries, across the modeled futures. This allocation reflects a balance between broad delivery coverage and the reallocation of shortage risk across the priority groups.

California: For California PPR, all alternatives, excluding the Enhanced Coordination Alternative, achieve the preferred minimum performance level of over 80 percent of normal delivery in 90 percent of years, across the first decade of the modeling period. Therefore, under all alternatives, excluding the Enhanced Coordination Alternative, there would be no shortage to California PPR across modeled futures. For California Priority 4, the No Action, Basic Coordination, and Supply Driven (LB Pro Rata approach) Alternatives achieve the preferred minimum performance of over 80 percent of normal delivery in 90 percent of years, across the first decade of the modeling period. The Maximum Operational Flexibility and the Representative Preferred Alternatives demonstrate the most robust performance for California PPR compared with other alternatives. However, for California Priority 4,

deliveries greater than 80 percent of normal delivery occurs in no potential futures under the Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives. Therefore, under these alternatives modeled delivery reductions could result in impacts on existing residents, economic sectors, and essential services reliant on domestic deliveries. Communities could experience increased constraints on existing and new residential and commercial development, need for additional adaptation measures, and greater pressure to accelerate development of replacement supplies.

When evaluating both California priority groups together, the Supply Driven Alternative (LB Pro Rata approach) is the most robust, compared with the No Action Alternative and all other action alternatives. It provides 100 percent of normal delivery to California PPR and California Priority 4 in 90 percent of years across 100 percent of potential futures. Additionally, considering the dead pool–related reductions, which could affect these users, the Supply Driven Alternative (LB Pro Rata approach) has the third lowest percentage of futures with constrained releases (12 percent), compared with all other alternatives. Reliable domestic water deliveries under the Supply Driven Alternative (LB Pro Rata approach) would support continued population growth and land development in areas served by California PPR and Priority 4.

Maintaining near-normal deliveries reduces the likelihood of constraints on planned and new development, housing availability, and municipal services that rely on water supply. In contrast, the alternatives with lower reliability or greater exposure to dead pool–related reductions could limit opportunities for residential and commercial growth, particularly in high-demand areas, and could influence land use patterns or delay new construction. Ensuring robust water delivery across multiple futures is therefore directly tied to supporting existing communities, sustainable population growth, and land use planning in California.

Nevada: Similar to Arizona PPR, for Nevada Priorities 1–7, all alternatives, excluding the Enhanced Coordination and Supply Driven (LB Pro Rata Approach) Alternatives, achieve the preferred minimum performance level of over 80 percent of normal delivery in 90 percent of years, across the first decade of the modeling period. In contrast, for Nevada Priority 8, the No Action Alternative is the only alternative that meets the preferred minimum performance. For Nevada Priorities 1–7 specifically, the Maximum Operational Flexibility Alternative is the most robust, followed by the Representative Preferred Alternative, compared with the No Action Alternative and the other action alternatives. In contrast, for Nevada Priority 8, these same alternatives are some of the least robust, with deliveries greater than 80 percent of normal occurring in only 1 percent of potential futures (Maximum Operational Flexibility Alternative) and no potential futures (Representative Preferred Alternative).

When considering both Nevada priority groups together, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, provide the most robust performance. These alternatives deliver greater than 60 percent of normal domestic water across the largest percentage of potential futures and for the greatest number of priority groups. Robust domestic water deliveries are critical to supporting existing communities and population growth and land development in Nevada. The alternatives that maintain more reliable deliveries for both priority groups reduce the risk of constraints on existing and new housing, commercial development, and essential municipal services that depend on water supply. Conversely, the alternatives with lower reliability, particularly for Nevada

Priority 8, could result in impacts on the capacity to support existing residents, economic sectors, and essential services reliant on domestic deliveries. Communities could experience increased constraints on existing and new residential and commercial development, impacts on the capacity of communities to expand, and effects on land-use patterns or delays to new construction projects. Modeled delivery reductions could result in the need for additional adaptation measures, and greater pressure to accelerate development of replacement supplies. By sustaining domestic water availability across a broad range of potential futures, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives may help support existing residents, economies, and essential services; stable population growth and more predictable land use planning across the state, where modeled deliveries remain reliable.

Issue 2: How would operational changes affect irrigated agricultural land use patterns?

Irrigated agriculture in Arizona and California remains sensitive to changes in Colorado River operations. Across all modeled alternatives, reductions in irrigation deliveries occur as reservoir elevations decline and system shortage volumes increase. Differences among the alternatives primarily reflect how shortages are distributed, either according to priority systems or through coordinated or pro rata sharing, and whether conservation and flexibility mechanisms are available to offset impacts.

Arizona experiences the greatest exposure to shortages under most alternatives because many irrigation users in Yuma, La Paz, and Mohave Counites hold junior priority rights. Under conditions without new conservation or shortage-sharing mechanisms, such as the No Action and Basic Coordination Alternatives, Arizona irrigation users face frequent and severe reductions. Literature indicates that these reductions can accelerate fallowing, crop switching, and farmland retirement in western Arizona counties (USGS 2019b; Arizona Extension 2024; Presson and Eden 2023). Even under the CCS Comparative Baseline, modeled shortages still affect Arizona at low to mid-levels of system stress, reflecting ongoing vulnerability despite existing conservation programs.

California agriculture, particularly in senior-rights districts, such as the Imperial Valley, is less affected under priority-based alternatives; however, it faces greater reductions under coordinated or pro rata frameworks. The Enhanced Coordination and Supply Driven (Pro Rata approach) Alternatives distribute shortages more evenly across Lower Basin water users, reducing concentrated impacts in Arizona but increasing exposure for California. Studies show that even modest reductions can influence land use in California's irrigation districts through shifts toward drought-tolerant crops or partial land retirement (Prakash 2023; Lee et al. 2020).

The alternatives that incorporate operational flexibility or large conservation reserves, such as the Maximum Operational Flexibility Alternative and portions of the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), may lessen the severity of shortages during milder hydrologic periods, though long-term reliability still depends heavily on conservation participation and system conditions. Research indicates that agriculture increasingly relies on adaptive practices, such as deficit irrigation and crop switching, to maintain productivity under prolonged water scarcity (USDA ERS 2021).

Up to 1.5 maf of shortage, the Representative Preferred Alternative for 2027-2028 would result in shortages similar to that under the Maximum Flexibility Alternative and the Supply Driven Alternative (LB Priority approach), with impacts concentrated on junior users. In the longer term (2029-2060)

modeled outcomes for the Representative Preferred Alternative follow the priority approach for distribution, and indicate potential for fallowing of land as noted under the Basic Coordination Alternative, with impacts concentrated on junior users.

The analysis shows that operational changes to the Colorado River system would continue to influence land use in irrigation-dependent regions. Concentrated shortages under priority-based operations are most likely to drive localized land fallowing and economic disruption in central Arizona, while pro rata or coordinated approaches lead to broader, more evenly distributed impacts in Arizona and California. More detailed modeling results and county-level outcomes are provided in the technical appendix.

Summary Comparison of Alternatives

Population and Developed Land Use: The alternatives vary in how they distribute domestic shortages and in their potential to impact domestic water deliveries and, in turn, indirectly impact population dynamics and land use within the analysis area.

As shown in **Table TA 17-17**, for the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, which apply a priority-based distribution of shortage, under most modeled futures, water users with senior entitlements would likely continue to experience relatively consistent domestic water deliveries. This is because these entitlements are contractually prioritized during periods of reduced supply. However, junior entitlements could face greater reductions in water deliveries during Shortage Conditions. Consequently, while senior entitlement holders may maintain service levels closer to normal, junior entitlement holders could experience more frequent or severe delivery constraints.

Under the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, greater than 80 percent of normal domestic delivery to most senior entitlements occurs in all potential futures. The specific Arizona, California, and Nevada senior entitlements vary by alternative (see **Table TA 17-17**). Because these alternatives have greater robustness for senior priority groups, there could be fewer potential indirect impacts on existing communities as well as population growth, and land development. A higher percentage of potential futures with greater than 80 percent of normal delivery could support existing populations, future population growth, water demand, and development in areas serviced by these priority groups.

Under the Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, for junior entitlements there are fewer potential futures, and in some cases no potential futures, in which there is any percentage of normal delivery across the first decade of the modeling period. The specific Arizona, California, and Nevada junior entitlements vary by alternative (see **Table TA 17-17**). Under the Enhanced Coordination, Maximum Operational Flexibility and Representative Preferred Alternatives, greater than 80 percent of normal domestic delivery to all junior entitlements occurs in no potential futures, across the first decade of the modeling period. Domestic shortages could manifest as reduced water allocations, delivery restrictions, or the need for additional adaptation and conservation measures, which could in turn limit the capacity to meet domestic water demand. Reduced capacity to meet domestic water demand could impact existing residents and essential services, constrain planned and future development, and create conveyance or treatment system challenges. The extent of these effects would vary by community

based on local water portfolios, infrastructure, regulatory context, conservation achievements, financing capacity, hydrologic conditions, and adaptation feasibility. Further, the shortage distributions applied under these alternatives could result in the complete loss of domestic water for these users. Should shortages result in a reduction or elimination of legal access to municipal water, widespread impacts on social and economic conditions could also be possible. For example, in some scenarios, municipalities could even find the need to pursue alternative water sources or hauled water, if available, as an alternative to support continued services. However, adaptation measures (for example, new supplies, infrastructure, treatment, interconnections, and related financing) can require substantial time and resources and may not be available on the same schedule for all communities. While these specific local project decisions would occur outside the scope of this Final EIS, it is important to note the potential for impacts. In addition, indirect social costs could occur as a result of a reduction in ecosystem services; also, indirect social costs could occur from a reduction of benefits to people provided by the environment. For example, trees in urban areas have been shown to provide high levels of benefits to people in the form of shade, which mitigates urban heat impacts (that is, heat-related illness), local air quality improvements, and enhancement of the visual setting. Should a reduction in domestic water supply result in die-offs of urban and suburban area trees, this could represent a loss of value that would take decades to recapture, due to the growth time required for trees (see, for example, Bloome et al. 2016).

As shown in **Table TA 17-17**, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which apply pro rata distribution of shortage under most modeled futures, would generally allow a larger number of priority groups to receive domestic water deliveries closer to normal conditions. While a pro rata approach would change the distribution of water across all users during shortages, this section solely focuses on the distribution of water to domestic users. This approach would deviate from the priority-based distribution, resulting in some modeled reductions to domestic deliveries for some senior entitlement holders who would otherwise maintain normal domestic delivery under the existing priority system. In contrast, more domestic junior priority water entitlement holders would continue to receive some level of water supply under this approach. In general, the pro rata method would result in more existing users receiving moderate water deliveries during shortages through a redistribution of water from senior entitlements.

Agricultural Land Use: The alternatives vary in how they distribute irrigation shortages and in their potential to influence long-term land use patterns. The No Action and Basic Coordination Alternatives rely on priority-based distribution and result in concentrated impacts on junior priority users in Arizona (primarily in Yuma, La Paz and Mohave Counites, with limited mitigation tools. These conditions increase the likelihood of fallowing, crop switching, and economic stress in affected communities.

The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives distribute shortages more broadly across the states and users, reducing concentrated impacts on junior priority holders but introducing greater reductions in California, which could lead to more widespread land use changes. The Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives incorporate adaptive tools and conservation reserves, offering potential buffers against extreme shortages; however, their effectiveness depends on stakeholder participation and hydrologic conditions.

Up to 1.5 maf of shortage, the Representative Preferred Alternative for 2027-2028 would result in shortages similar to those under the Maximum Operational Flexibility Alternative and the Supply Driven (LB Priority Approach), with impacts concentrated on junior users. In the longer term (2029-2060) modeled outcomes indicate potential for the greatest level of shortage to junior priority users of any alternative. However, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative, as a result, the potential for fallowing, crop switching, and other associated long term land -use patterns in any given area may vary and impacts may be mitigated in part by specific operational guidelines.

3.18 Indian Trust Assets

3.18.1 Affected Environment

The U.S. has a trust responsibility to tribes as defined by statutes, court decrees, treaties, or other applicable law.[22] ITAs are legal interests in assets held in trust by the federal government for the benefit of federally recognized Native American tribes or individual Native Americans (Reclamation 1994). ITAs can be located on or off established reservation lands and can consist of land, water entitlements;[23] natural resources; monies, such as trust funds; mineral rights; hunting, fishing, trapping, and gathering rights; and others. Beneficiaries of the Indian trust relationship are tribes and individual Native Americans; the U.S. is the trustee. ITAs are generally restricted against alienation (that is, they cannot be sold, transferred, abandoned, or lost without approval from the Secretary of the Interior). With federal authority and approval, ITAs may be leased to generate income for tribes or individual Native Americans (Department 2025).

It is the general policy of the Department to carry out activities in a manner that protects ITAs and avoids adverse effects whenever possible (Reclamation 1993). In accordance with Reclamation ITA policy and guidance (Reclamation 1994), tribal consultation addressing trust assets should be initiated with appropriate tribal groups and the Bureau of Indian Affairs (BIA), and the presence or absence of ITAs should be addressed explicitly in all NEPA documents. Reclamation has consulted with tribes regarding the proposed Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead Environmental Impact Statement.

The following sections summarize the affected environment for different types of ITAs. See **TA 18**, Indian Trust Assets, for additional detail.

Trust Lands

Indian trust lands are lands that the U.S. holds in trust for the benefit of a tribe (tribal trust land) or for an individual Native American (individual trust land). Trust lands may be located on or off a reservation. While reservations are not always synonymous with trust lands, the exterior boundaries of reservations are used to define the trust land assets for purposes of this NEPA analysis, to be

[22] Nothing in this technical appendix is intended to modify, abrogate, or create ITAs. Any particular ITA remains defined by and subject to applicable authority.

[23] Rights and entitlements may be used interchangeably in this technical appendix for simplicity, and no legal change to any ITA is intended.

inclusive. There are 30 federally recognized tribes in the Colorado River Basin; 29 of these have established reservations. Tribal land uses include, but are not limited to, communal and spiritual uses, domestic use, and agriculture and economic development.

Water Entitlements, Water Deliveries, and Storage and Conservation Options

The management and operation of the Colorado River and delivery of its waters to various users is governed by a complex set of treaties, statutes, Supreme Court decrees, and other settlements and agreements collectively known as the "Law of the River". In general terms, the Law of the River establishes a priority system for the distribution of available water. Higher priority (senior) water entitlements are filled first, and lower priority (junior) entitlements are filled next. Some tribal water entitlements have higher priorities and others are lower priorities. **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation, provides more detail on the priority of each tribal water entitlement in the Lower Basin.

TA 4, Water Deliveries, provides more detail on the Law of the River. **TA 18**, Indian Trust Assets, includes a discussion of tribal mainstream Colorado River water entitlements and CAP contracts.[24] The entitlements included in this analysis are consistent with those in the SAMs and ADMs (see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation) and other sections of the EIS.[25]

Other Indian Trust Assets

ITAs can also include hunting, fishing, trapping, and gathering rights; mineral rights; and cultural, biological, and other resources. Whether specific rights or resources legally qualify as an ITA is complicated and depends on multiple factors, such as land status (Reclamation 1994). Reclamation consulted with tribes and the BIA to identify ITAs. To date, potential changes in water deliveries and activities affected by potential changes in water deliveries (for example, irrigated agriculture) have been the primary concerns related to ITAs.

Reclamation acknowledges that the 30 Basin Tribes depend on the Colorado River and its tributaries for a variety of purposes, including cultural and spiritual activities, wildlife, instream flows, recreation, and other purposes. See **TA 13**, Tribal Resources, and **TA 11**, Cultural Resources, for analysis of tribal and cultural resources, respectively. In general, those analyses apply to tribal and cultural resources that qualify as ITAs.

Although income derived from ITAs is not an ITA in and of itself, income derived from ITAs, such as agricultural products, water leases, and fees charged for outdoor recreation on tribal land, can be an important source of income for tribes.

3.18.2 Environmental Consequences

Following Reclamation ITA policy (Reclamation 1994), the following analysis discusses actions that affect the value, use, or enjoyment of ITAs.

[24] While some entitlements are not ITAs, they are included for reference in **TA 18**, Indian Trust Assets.
[25] Tribes may have other sources of water, including groundwater and other surface water, which are not part of this analysis.

Methodology

The methodology varies for each type of ITA. Quantitative metrics are analyzed where possible; otherwise, a qualitative discussion is provided. Refer to **Section TA 18.2.1**, Methodology, for more information on the methodology used. As described in **Section 3.4.1**, the geographic scope of this EIS does not extend above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users.

Impact Analysis Area

The impact analysis area includes land within the boundaries of reservations and off-reservation trust land within the Colorado River Basin (29 reservations are listed in **Section TA 18.1**).[26]

Assumptions

- Trust land includes land within the borders of established reservations and off-reservation trust land.
- For the water deliveries analysis, the assumptions of the CRSS modeling (**Appendix A**, CRSS Model Documentation) and SAM modeling (**Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation) apply.
- For potential impacts on agricultural land, the assumptions of the agricultural modeling apply (see **TA 16**, Socioeconomics, for more details).

Impact Indicators

- Percentage of normal water entitlement delivered to Upper and Lower Basin Tribes
- Changes in acres of irrigated tribal agricultural land in the Lower Basin

Issue 1: How would changes in dam operations affect tribal water rights, water deliveries, and water storage and conservation options?

With respect to potential tribal water deliveries, the alternatives can be distinguished based on the following characteristics:

- The maximum shortage, which affects the relative frequency and severity of Lower Basin water shortages, including potential dead pool–related reductions (that is, releases reduced by low Lake Mead levels or outlet limits).
- The approach used to distribute Lower Basin water under shortages.
- Options for tribes and other water users to conserve and store water in Lake Powell or Lake Mead.

Figure TA 18-2 and **Table TA 18-5** in **TA 18**, Indian Trust Assets, summarize the alternatives based on these characteristics. The following sections summarize the anticipated effects of the alternatives on water deliveries and the storage and conservation options.

[26] As discussed in **Section 3.18.1**, one of the 30 Basin Tribes does not have an established reservation; therefore, there are 29 reservations.

Upper Basin

Water Entitlements and Deliveries

No alternative would affect Upper Basin tribal water entitlements or deliveries.

Storage and Conservation Options

The No Action and Basic Coordination Alternatives have no new water storage mechanisms and would not affect water storage and conservation by Upper Basin Tribes. The other four alternatives, including the Preferred Alternative, do have new storage and conservation mechanisms. See **Chapter 2**, Description of Alternatives, and **Appendix S**, Additional Description of Alternatives, for a full description of these mechanisms and how they would operate. Note that in all cases, stored water would be available for water transactions with other Upper Basin water users, both within and across Upper Division States.

Lower Basin

Water Entitlements

The approaches to distributing Lower Basin shortages incorporated in all alternatives are designed to explore a wide range of potential concepts and impacts; they do not reflect an intention by Reclamation to alter apportionments or water entitlements. However, because the concepts would affect a range of users, impacts on deliveries to different entities are analyzed, and addressed in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

Water Deliveries

In this analysis, three main factors combine to determine the potential Lower Basin tribal water deliveries in any given year:[27] (1) the magnitude of potential shortages, (2) the distribution method used to allocate water under shortages, and (3) the frequency of dead pool–related reductions.[28] This analysis focuses on the first two factors. The third factor, dead pool–related reductions, is not a focus of this analysis.

Figure TA 18-3 in **TA 18**, Indian Trust Assets, illustrates how the percentage of normal water delivery changes as shortages become more severe under different distribution methods. For the purposes of this analysis, tribes are aggregated into the following four groups based on entitlement priorities:[29]

- The "AZ CAP NIA" group has the most junior entitlements and includes tribes with Arizona CAP NIA-A and NIA-B priorities. This group consists of four tribes with contracts totaling approximately 177,000 afy.
- The "AZ CAP Indian, CAP M&I, and AZ 4i" group includes tribes with Arizona CAP Indian, CAP M&I, and Arizona 4i priorities. This group consists of 13 tribes and 16 individual entitlements (including mainstream water reserved for future settlement and unallocated), totaling approximately 374,000 afy.

[27] The phrase "potential water deliveries" is intended to recognize that some tribal water entitlements are not fully developed or utilized. For simplicity, this analysis assumes that water deliveries and water entitlements refer to the same quantities of water.
[28] Discussion of dead pool–related reductions can be found in **TA 4**, Water Deliveries.
[29] The number of tribes, water entitlements, and amounts listed below come from the SAM (see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, for modeling assumptions and descriptions of priority nomenclature).

- The "AZ 3" includes one tribe with Arizona third priority, totaling 50,000 afy.
- The PPR group is the most senior entitlements; this group includes five tribes in all three Lower Division States. This group of five tribes includes 15 discretely quantified entitlements totaling approximately 503,000 afy.

The DMDU analysis integrates information on the percentage of futures in which different amounts of shortages are estimated to occur under the different alternatives. For tribal water deliveries, deliveries of 20, 40, 60, and 80 percent of normal deliveries are modeled. The results show the percentage of futures in which these thresholds are met in 90 percent or more of the years within each modeled future.

The DMDU figures are presented in **Figure TA 18-4** through **Figure TA 18-12** in **TA 18**, Indian Trust Assets. Solely for the purposes of considering vulnerability within the DMDU modeling framework, a "preferred minimum performance" outcome is defined as a future trace in which at least 80 percent of normal water deliveries are estimated to be delivered in at least 90 percent of the years in a modeled future. In contrast, an "undesirable performance" future means that the preferred minimum performance criteria are not met. The 80 percent threshold was chosen as the preferred minimum performance because it is the model outcome with the largest quantity of water delivered.[30]

Key findings differentiating the alternatives based on the full-period DMDU modeling are listed below. See **Section TA 18.2.2** for additional details, including key findings by priority group.

- There is no alternative that is the most robust across the priority groups in terms of maximizing water deliveries to all tribes. The alternatives perform differently for the priority groups. For some priority groups, the performance depends on the importance placed on results, considering only shortages relative to the frequency of futures with dead pool–related reductions.
- Considering shortages only (that is, not considering dead pool–related reductions), the No Action Alternative is estimated to meet the preferred minimum performance criteria in 100 percent of normal water deliveries to all priority groups except the AZ CAP NIA group. This result is likely due to a lower maximum shortage compared with the other alternatives. However, the No Action Alternative has the highest potential for dead pool–related reductions of any alternative, with 70 percent of futures estimated to have dead pool–related reductions. Therefore, water delivery would be unlikely under the No Action Alternative.
- The CCS Comparative Baseline is similar to the No Action Alternative, except 22 percent of futures meet the preferred minimum performance criteria for the CAP Indian, CAP M&I, and AZ 4i priority group, and 6 percent of futures meet the preferred minimum performance criteria for the CAP NIA group. Dead pool–related reductions are estimated to occur in 50 percent of modeled futures, which is less frequent compared with the No Action Alternative.
- The Representative Preferred Alternative is the second-best performer for the PPR priority group. It is not among the most robust alternatives for any other priority group. Impacts under the Preferred Alternative may be different from what is shown in the DMDU figures for the Representative Preferred Alternative, as this alternative provides a framework that allows for

[30] In this context, "preferred minimum performance" and "undesirable performance" are terms selected to understand a modeling analysis, and they do not imply any policy, legal conclusion, or other conclusions about the analysis or ITAs.

shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**.

- The Basic Coordination Alternative is not among the most robust alternatives for any priority group.
- The Enhanced Coordination Alternative has a more complicated pattern of robustness. Twenty-one percent of futures meet the preferred minimum performance criteria for all priority groups; this is less than some other alternatives. This is likely because shortages start relatively early compared with the other alternatives, and there is a high maximum shortage (see **Figure TA 18-2** and **Table TA 18-5** in **TA 18**, Indian Trust Assets). However, this alternative performs well in terms of delivering at least 60 percent of normal water, as it does so in 91–100 percent of modeled futures for all priority groups. This result is likely due, in part, to its use of the pro rata distribution method. Finally, this alternative has 16 percent of futures with dead pool–related reductions, which is among the fewest of the options modeled.
- Considering only shortages, the Maximum Operational Flexibility Alternative is more robust than the Enhanced Coordination Alternative for the two more senior water entitlements groups (PPR and AZ 3) and is less robust than the Enhanced Coordination Alternative for the two less senior water entitlements groups (AZ CAP Indian, M&I, and 4i; CAP NIA). It has the lowest percentage of futures with dead pool–related reductions (9 percent) of all the options modeled.
- The Supply Driven Alternative (LB Priority approach) generally is similar or less robust than the Maximum Operational Flexibility Alternative with respect to shortages for three of the four priority groups and has a higher percentage of futures with dead pool–related reductions (24 percent).
- The Supply Driven Alternative (LB Pro Rata approach) is closest to the Enhanced Coordination Alternative but does not meet the preferred minimum performance criteria as often; therefore, it is less robust.
- It is important to consider the first decadal subperiod, as the Preferred Alternative is a 10-year decision framework. The conclusions above all hold for the first decadal subperiod with the one exception: for the Arizona Priority 3 group, a case could be made that either the Maximum Operational Flexibility, Supply Driven (LB Priority approach), or Representative Preferred Alternatives are the best performing.[31] These three alternatives have various trade-offs between water deliveries considering only shortages and the percentage of futures with a dead pool-related reduction.

Storage and Conservation Options

The No Action and Basic Coordination Alternatives have no water storage mechanisms that would affect Lower Basin Tribes or the quantities of water available to them. Under both alternatives, water conserved under previous mechanisms that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. The other four alternatives do contain new water storage and conservation mechanisms. See **Chapter 2**, Description of Alternatives, for a full description of these mechanisms and how they would operate. Note that in all cases, stored water would be available for

[31] In the full period results, the Maximum Operational Flexibility Alternative performs better than the Representative Preferred Alternative.

water transactions with other Lower Basin water users, both within and across the Lower Division States. The Enhanced Coordination Alternative is unique in that it explicitly allows for compensating tribes for water used to contribute to a federally managed conservation pool in Lake Mead. See **Section TA 18.2.2** for additional details.

Issue 2: How would changes in dam operations affect Indian trust lands?

Changes in dam operations under the different alternatives would not affect the borders of established reservations or the definitions of any trust lands. Trust land will remain trust land. Future potential acquisitions of land into trust are not limited by the operations. Further, in addition to (uncontrollable) drought conditions in any given year, the different alternatives of various distributions of the available water could add an incremental impact on the use of trust lands. An important aspect of the use of trust lands involves agricultural land, as fluctuations in water levels are estimated to result in some tribal agricultural lands being fallowed. Other changes in the use of tribal land and resources are discussed in **TA 13**, Tribal Resources. The considerations therein generally apply to Trust and non-Trust resources.

Agricultural Land

The potential impacts of changes in dam operations on agricultural land are assumed to be inversely dependent on water deliveries, meaning agricultural impacts are estimated to increase as water deliveries decrease.

Upper Basin

As noted in the Upper Basin water deliveries section above, none of the alternatives, including the Representative Preferred Alternative, would directly or indirectly affect water deliveries to Upper Basin Tribes. However, changes in storage and conservation options under some alternatives could provide opportunities for tribal participation. All else equal, the new mechanisms for conserving and storing water for Upper Basin Tribes (contained in the Preferred, Enhanced Cooperation, Maximum Operational Flexibility, and Supply Driven [both LB Priority and LB Pro Rata approaches] Alternatives) would provide additional options for tribes in the Upper Basin.

Lower Basin

TA 16, Socioeconomics, discusses the potential impacts of changes in dam operations and resulting changes in water deliveries on tribal and non-tribal agricultural economies in the Lower Basin. Estimates are presented for several socioeconomic metrics: acres of fallowed agricultural land, direct market value, jobs, and economic output. Results are presented at the state level and by priority groups for Arizona, California, and Nevada. See **TA 16**, Socioeconomics, for a full discussion of the modeling and results. This section focuses on the acres of fallowed land as an indicator of potential impacts **to** Trust land.

Table TA 18-6 summarizes the modeling results for estimated changes in fallowed tribal agricultural land. Some key findings include the following:

- As indicated in the Lower Basin water deliveries analysis above, the seniority of water entitlements combined with the distribution method makes a large difference in the results.
- Tribal agriculture in Arizona is estimated to experience the largest impacts in terms of the absolute changes in acres of fallowed land. This is likely because the majority of the

reservation land is in Arizona (see **Figure TA 18-1** in **TA 18**, Indian Trust Assets). The Representative Preferred Alternative is would fallow the second-least number of acres in Arizona, relative to the other alternatives.

- No alternative is clearly the most robust for Arizona. The different alternatives and the CCS Comparative Baseline have varying trade-offs between fallowed acreage under shortages and the percentage of futures with dead pool–related reductions.
- In California and Nevada, impacts are only associated with the alternatives that use the pro rata distribution (the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives). All the other alternatives, including the Representative Preferred Alternative, and the CCS Comparative Baseline use some variation of the priority system and estimate no reductions in water deliveries; therefore, there would be no fallowed agricultural land in these states.
- The Maximum Operational Flexibility Alternative performs the best for California and Nevada; this is because there are zero fallowed acres and the percentage of futures with dead pool–related reductions are minimized. This would be true for PPRs in Arizona as well.

Issue 3: How would changes in dam operations affect other ITAs?

Changes in dam operations would not directly affect the status and corpus of other ITAs. Trust assets will remain trust assets. Future potential acquisitions of assets into trust are not limited by the operations. Further, in addition to (uncontrollable) drought conditions in any given year, changes in dam operations could incrementally affect water levels, vegetation, fish, and wildlife, and therefore could indirectly affect the use of ITAs. General changes in vegetation, fish, and wildlife are discussed in their respective sections of this Final EIS.

Summary Comparison of Alternatives

How the alternatives affect ITAs depends on the type of ITA and other factors. For both irrigated agriculture and water deliveries in the Lower Basin, the most robust alternative depends on the interactions between the priority of water entitlements, the maximum shortages, and the percentage of futures with dead pool–related reductions. See **Section TA 18.2.8**, Summary Comparison of Alternatives, for more detailed summary comparisons of the alternatives by the type of ITA, basin, and priority group.

In general, the action alternatives are more robust than the No Action Alternative for water deliveries and irrigated agricultural land. All else equal, the action alternatives that use a variation of the priority distribution method (the Representative Preferred, Basic Coordination, Maximum Operational Flexibility, and Supply Driven [LB Priority approach] Alternatives) are more robust for more senior water entitlements; the action alternatives that use a variation of the pro rata distribution method (the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives) are more robust for more junior water entitlements.

3.19 Visual Resources

3.19.1 Affected Environment

Visual resources are the physical features that make up the visible landscape, including land, water, vegetation, topography, and human-made features such as buildings, roads, utilities, and structures. They also include the response of viewers to those features.

Visual resources are important both to visitors to GCNP, Glen Canyon NRA, and Lake Mead NRA and to the Basin Tribes who use these lands for subsistence or ceremony uses. The Grand Canyon Protection Act of 1992 specifically calls for the conservation of visual resources, which are also a key component of federal management of these areas. GCNP, Glen Canyon NRA, and Lake Mead NRA are managed under their general plans which identify management direction for visual resources as part of their general management plan, which is described in **TA 19.1**, Affected Environment, in **TA 19**, Visual Resources.

Lake Powell and Glen Canyon Dam

Landscape Character

The landscapes of the Lake Powell and Glen Canyon area are characterized by sweeping vistas of red rock towers, buttes, and mesas typical of the Colorado Plateau (Fenneman 1931). Navajo Sandstone and desert varnish dominate the existing landscape character with Lake Powell framing these natural features. Lake Powell has deposits of calcium carbonate, which become visible as reservoir levels decrease. At lower lake elevations, the colorful sandstone canyon walls show a light-toned band of calcium carbonate deposit between the full reservoir elevation and the lower reservoir elevation; these deposits contrast with the natural, red-colored sandstone (see **Figure TA 19-1**, in **TA 19**, Visual Resources). Additionally, sediment deltas have formed near the inflow areas of Lake Powell as a result of sediments carried by the Colorado River and the San Juan, Dirty Devil, and Escalante Rivers, resulting in downstream-progressing deltas. These appear as expansive, deep, and eroding mud flats cut by river channels. For more information on existing landscape character, refer to **TA 19.1**, Affected Environment, in **TA 19**, Visual Resources.

Attraction Features

The analysis focuses on Cathedral in the Desert and Glen Canyon Dam, consistent with the 2007 Final EIS and 2024 Final SEIS. These were selected to focus on visibility of specific geologic features and large-scale built structures associated with each reservoir. Note that the discussion of potential impacts on recreation sites and other viewing locations is described under Issue Statement 2. For more information on these attraction features, see **TA 19.1**, Affected Environment, in **TA 19**, Visual Resources.

Lake Mead to Hoover Dam

Landscape Character

The landscapes of the Lake Mead and Hoover Dam area are similar to those described for the Lake Powell area, except the adjacent landscapes are more typical of the Basin and Range region, characterized by parallel, north–south-oriented mountain ranges surrounded by nearly level, typically undrained basins (Fenneman 1931). Similar to Lake Powell, Lake Mead has deposits of calcium

carbonate that contrast with the natural rock colors. For more information on existing landscape character, refer to **TA 19.1**, Affected Environment, in **TA 19**, Visual Resources.

Attraction Features

The analysis will focus on Hoover Dam, consistent with the 2007 Final EIS and 2024 Final SEIS. For more information on this attraction feature, see **TA 19.1**, Affected Environment, in **TA 19**, Visual Resources.

Hoover Dam to SIB

The landscapes from the Hoover Dam area to the SIB are characterized by arid mountain ranges and intervening desert plains associated with the Basin and Range region (Fenneman 1931). The availability of Colorado River water has resulted in large areas of irrigated landscapes, including agricultural lands in Arizona, California, and Nevada (Lower Division States), which have altered the natural landscapes. This increased water availability has introduced vivid greens associated with crops and ornamental plantings into these landscapes and has expanded the influence of the Colorado River into adjacent arid lands beyond the narrow, natural riparian corridor.

3.19.2 Environmental Consequences

Methodology

Reclamation used methods similar to those in the 2007 Final EIS and 2024 Final SEIS to analyze potential impacts on visual resources. This analysis assesses the potential effects on attraction features, the extent of the visible calcium carbonate ring, and exposure of sediment deltas at reservoir inflow areas, while incorporating the DMDU framework for this EIS. Additionally, this analysis considers the effects of expanded shoreline exposure on the area's landscape character.

Using modeling and DMDU concepts, the analysis first focuses on the percent of time during the planning window that Lake Powell would decrease below elevation 3,550 feet. At that elevation, Cathedral in the Desert and other geological attraction features—including Gregory Bridge, La Gorce Arch, and other features inundated by Lake Powell—would become visible and accessible. Based on historical averages, Lake Powell was below 3,550 feet approximately 9.9 percent of months between October 2007 and May 2025. The alternatives comparison focuses on maintaining this lake elevation for at least 10 percent of the months during the planning window. Conversely, this analysis also identifies the percentage of preferred minimum performance futures in which Lake Powell would be above 3,550 feet, resulting in less of the upstream side of Glen Canyon Dam being visible, as higher reservoir levels obscure the structure.

The potential height of the calcium carbonate ring was calculated by comparing differing reservoir elevations with the full pool elevations of Lake Powell (3,700 feet) and Lake Mead (1,229 feet) under DMDU concepts. The assessment of effects from sediment deltas and shoreline exposure considers these differing reservoir elevations and references the analysis conducted in the 2007 Final EIS.

Reclamation added two new analysis items, similar to the 2024 Final SEIS, to assess impacts on the Colorado River's landscape character and broader landscape character in the Lower Division States. This assessment is based on changes in modeled hydrologic conditions under the No Action Alternative and CCS Comparative Baseline, as well as management direction associated with the action

alternatives. To assess potential changes to the landscape character along the Colorado River (between Glen Canyon Dam and Lake Mead), this analysis includes a qualitative assessment of effects associated with lower flow rates and the potential inability to conduct HFEs from Glen Canyon Dam. For more information on historic flow rates along the Colorado River, refer to **Section TA 19.2.1**, Methodology, in **TA 19**, Visual Resources, and **Section 3.3**, Hydrologic Resources**.**

The assessment of potential impacts on the broader landscape character in the Lower Division States considered changes in annual Colorado River water supplies available to these states. This assessment identifies the extent of large-scale changes in visual character in irrigated landscapes, including changes associated with agricultural production through shortages and the potential for Lake Mead to reach dead pool–related reductions, as described in **Section 3.4**, Water Deliveries. This analysis considers and references assessment items contained in **Section 3.16**, Socioeconomics, including the effect of each alternative's proposed distribution of water on agricultural operations and the effect of increased dust generation from aridification of exposed lands, as described in **Section 3.7**, Air Quality, potentially impacting visibility and views within GCNP and other visually sensitive landscapes.

Impact Analysis Area

The visual resources impact analysis area was defined as the area within 5 miles of the Colorado River from Lake Powell to the SIB, including the full pool elevations of Lake Powell and Lake Mead. Visual effects beyond this geographic area were considered where appropriate, including the potential effects on the broader landscape character associated with potential decreased water availability for the Lower Division States. For more details on the impact analysis area, refer to **Section TA 19.2.1**, Methodology, in **TA 19**, Visual Resources.

Assumptions

- The analysis methods are consistent with the 2007 Final EIS and 2024 Final SEIS. Attraction features analyzed include Cathedral in the Desert, Glen Canyon Dam, and Hoover Dam.
- Decreasing flow rates along the Colorado River, and the potential inability to conduct HFEs from Glen Canyon Dam, would modify the river corridor's natural, visual character by limiting natural flooding processes.
- This EIS references the analysis from the 2007 Final EIS and 2024 Final SEIS regarding impacts associated with expanding sediment deltas.
- Decreasing water availability for the Lower Division States would result in large-scale changes to the visual character of irrigated landscapes, including those associated with agricultural production.

Impact Indicators

- Attraction features: Qualitative assessment describing effects on visibility and access to Cathedral in the Desert and effects from increased visibility of the upstream sides of Glen Canyon Dam and Hoover Dam, informed by the CRSS and DMDU analyses. Quantitative analysis showing the percentage of futures that meet the preferred minimum performance level where Lake Powell is below 3,550 feet (and thus Cathedral in the Desert would be visible and accessible) in at least 10 percent of months under each alternative. Conversely, this analysis

identifies the percentage of futures that meet the preferred minimum performance level in which Lake Powell is above 3,550 feet, reducing visibility of the dam's upstream face.

- Calcium carbonate rings: Comparison of modeled ring height (feet) at Lake Powell and Lake Mead under each alternative, considering the CRSS and DMDU analyses.
- Exposed shoreline and sediment deltas: Qualitative assessment referenced from the 2007 Final EIS and 2024 Final SEIS, considering differing reservoir elevations under each alternative, to assess receding shorelines and formation of sediment deltas resulting from lower reservoir elevations.
- Colorado River landscape character: Qualitative description of the effect associated with proposed flow rates and the potential to conduct HFEs from Glen Canyon Dam under each alternative, considering modeling presented in **Section 3.9**, Vegetation Including Special Status Species; **Section 3.5**, Geomorphology and Sediment; **Section 3.14**, Recreation; and **Section 3.7**, Air Quality.
- Broader landscape character: Qualitative description of the effects associated with potential decreases in water availability for the Lower Division States on the broader landscape character. This includes considering modeling associated with potential changes to crop production resulting from proposed distribution of water, as described in **Section 3.16**, Socioeconomics, as well as the potential for Lake Mead to reach dead pool–related reductions as described in **Section 3.4**, Water Deliveries.

Issue 1: How would management of reservoir elevations affect visibility of attraction features?

The assessment of impacts on landscape character associated with the elevations of Lake Powell considers two concepts. The assessment notes that some visitors view visibility and access to Cathedral in the Desert and other attraction features inundated by Lake Powell (below 3,550 feet) as a benefit, while others prefer higher water levels. For more information on the first portion of this issue, refer to **Section TA 19.2.2**, Visibility of Attraction Features, in **TA 19**, Visual Resources.

The second part of the analysis focuses on keeping the Lake Powell water levels high, which reduces the visibility of Glen Canyon Dam, specifically when above 3,550 feet. As reservoir levels drop and more of the dam is exposed, its visual prominence increases and can dominate the surrounding landscape. As shown in **Figure TA 19-3** in **TA 19**, Visual Resources, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in more preferred minimum performance futures where less of the upstream side of Glen Canyon Dam is visible because higher water levels obscure the structure. Lower flows could keep Lake Powell at higher elevations under the Enhanced Coordination and Maximum Operational Flexibility Alternatives compared with the CCS Comparative Baseline, No Action Alternative, Basic Coordination Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as during the full modeling period except the Enhanced Coordination Alternative, which would have a smaller percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative exhibits a similar performance as the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives

for the first 10 years (modeled 2027-2039 period) with the results being within the range analyzed associated with these alterantives.

As shown in **Figure TA 19-4** in **TA 19**, Visual Resources, comparing DMDU modeling with the driest historic 10-year average flows, the CCS Comparative Baseline, No Action Alternative, Basic Coordination Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would require higher flows to maintain similar elevations, which makes those alternatives more vulnerable to missing the preferred minimum performance level. Specifically, those alternatives would be more vulnerable than the Enhanced Coordination and Maximum Operational Flexibility Alternatives, with over 75 percent of traces in the reference hydrology exhibiting conditions resulting in the potential for Lake Powell to decrease below 3,550 feet for 10 percent or more of months during the planning period. Based on updated modeling, approximately 50 percent of traces in the reference hydrology under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternatives exhibit conditions that are expected to result in Lake Powell falling below 3,550 feet for 10 percent or more of the planning period. The Representative Preferred Alternative exhibits a similar performance as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) with the results being within the range analyzed associated with these alternatives.

Modeling of lake levels within Lake Powell and Lake Mead indicates that, under the CCS Comparative Baseline and the No Action, Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives, Hoover Dam visibility follows the same pattern described for Glen Canyon Dam. Under the Basic Coordination Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), based on managing higher reservoir levels in Lake Mead than in Lake Powell, less of the upstream side of Hoover Dam would be visible, with comparatively more of the upstream side of Glen Canyon Dam being visible, as described above. Therefore, as Lake Mead reservoir levels decrease, exposing more of the dam's concrete structure, its effect on the area's landscape character would increase and further dominate the landscape character.

Issue 2: How would management of reservoir elevations affect landscape character, including visibility of calcium carbonate rings, exposed shoreline, and sediment deltas?

The assessment compares how often modeled futures fall into reservoir elevation ranges relative to full pool, and relates those ranges to changes in landscape character. This difference in reservoir elevations creates a light-toned band of calcium carbonate deposit as well as generating larger sediment deltas and exposing more shoreline. The lower the lake levels become, the impacts on landscape character increase including effects from calcium carbonate rings, exposed shoreline with trash and other debris, and sediment deltas. To compare alternatives, the assessment focused on whether calcium carbonate rings would exceed historic maximums at any time during the planning period.

For Lake Powell, the tallest calcium carbonate ring, which occurred in February 2023, was 179 feet tall. As shown in **Figure TA 19-5**, **Figure TA 19-6**, and **Figure TA 19-7** in **TA 19**, Visual Resources, based on updated modeling, all alternatives would exceed the historical maximum during the modeling period. In looking at a higher threshold of 200 feet tall, the CCS Comparative Baseline and the No Action Alternative, Basic Coordination Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would result in more futures where the calcium carbonate rings would exceed the 200-foot maximum during the modeling period. Only 5 percent, 4 percent, 13 percent, and 18 percent of futures under these alternatives, respectively, would result in calcium carbonate rings

being less than 200 feet tall for all the months of modeling. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as the full modeling period except all the action alternatives would result in slightly higher percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative would potentially exceed the 200-foot maximum height, with 45 percent of futures resulting in calcium carbonate rings being less than 200 feet for all months of modeling for the first 10 years (modeled 2027-2039 period) and 24 percent of futures during the full modeling period, with these results within the range analyzed associated with these alterantives.

For Lake Mead, the tallest calcium carbonate ring, which occurred in July 2022, was 180 feet. As shown in **Figure TA 19-8**, **Figure TA 19-9**, and **Figure TA 19-10** in **TA 19**, Visual Resources, based on updated modeling, all alternatives would exceed the historical maximum during the modeling period except for the Supply Driven Alternative (LB Pro Rata approach) which would have a 1 percent of futures where this threshold is not exceeded. In looking at a higher threshold of 200 feet tall, the CCS Comparative Baseline and the No Action Alternative would result in more futures where calcium carbonate rings would exceed the 200-foot maximum during the modeling period, with only 13 percent and 6 percent of futures under these respective alternatives resulting in calcium carbonate rings being less than 200 feet tall for all the months of modeling. Under the Basic Coordination Alternative, Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), these percentages would increase to 16 percent, 14 percent, 20 percent, and 40 percent, respectively. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as the full modeling period with all alternatives, including the No Action Alternative, resulting in slightly higher percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative would likely exceed the 200-foot maximum height, with 23 percent of futures resulting in calcium carbonate rings being less than 200 feet for all months of modeling for the first 10 years (modeled 2027-2039) and 17 percent of futures during the full modeling period, with these results within the range analyzed associated with these alterantives.

As described in the 2007 Final EIS, sediment deltas would continue to build up over time and would be visible as the reservoir elevations decrease, including under the No Action Alternative. The expanding sediment deltas would become populated by vegetation, including tamarisk, which would introduce into the landscape bright greens that would contrast with the arid landscapes adjacent to Lake Powell and Lake Mead. Additionally, the receding shorelines would expose trash and other debris, which would diminish the area's landscape character. The lower the lake levels become, impacts on landscape character associated with calcium carbonate rings, exposed shoreline with trash and other debris, and sediment deltas would increase. Additionally, lower lake levels would facilitate re-emergence of side canyons including public access for recreation (see **Section 3.14**, Recreation). The calcium carbonate ring, exposed shoreline with trash and other debris, and sediment deltas would modify the landscape character along the edge of Lake Powell. These modifications would be visible for motorists on Utah State Route 95, boaters on Lake Powell, recreationists at developed and undeveloped recreation areas, and hikers on trails adjacent to Lake Powell. Similarly, the calcium carbonate ring, exposed shoreline with trash and other debris, and sediment deltas would modify the landscape character along the edge of Lake Mead; these modifications would be visible for motorists on US

Highway 93 (between Boulder City, Nevada, and the Hoover Dam), boaters on Lake Mead (including visitors to Overton Beach and Pearce Ferry), and hikers on trails adjacent to Lake Mead.

Issue 3: How would management of releases from Glen Canyon Dam affect landscape character along the Colorado River?

The No Action Alternative and the CCS Comparative Baseline would include lowering releases from Glen Canyon Dam as Lake Powell elevations decrease; this would result in releases as low as 7.0 maf when elevations drop below 3,525 feet. Since neither the No Action Alternative nor the CCS Comparative Baseline would reduce releases from Glen Canyon Dam under 7.0 maf, including if Lake Powell drops below power pool but remains above dead pool, there would be minor, incremental impacts on the landscape character along the Colorado River, including through the Grand Canyon. The current trend of increasing bank armoring associated with expanding riparian vegetation areas (including tamarisk) would continue under the No Action Alternative and CCS Comparative Baseline. If the elevation of Lake Powell were to drop below dead pool, flows from Glen Canyon Dam could dramatically decrease, resulting in more extensive impacts on the landscape character, including the appearance of river features not visible under current conditions. Additionally, the positive influence of the moving, turbulent Colorado River adds to the existing landscape character, which would be degraded if releases from Glen Canyon Dam were dramatically reduced. The No Action Alternative would result in relatively short and few HFE releases, providing fewer opportunities for sand bar volumes to increase compared with the CCS Comparative Baseline, which would result in longer and more frequent HFE releases with more opportunities for increased sand bar volumes.

The Basic Coordination Alternative would result in impacts similar to those under the No Action Alternative and CCS Comparative Baseline, since it includes a similar range of releases from Glen Canyon Dam, but would include an increased number of futures where HFEs are conducted. The Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) would include lower releases—as low as 4.7 maf, which is lower than historical minimum flows. Lower releases from Glen Canyon Dam would result in less water flowing along the Colorado River (and through the Grand Canyon), which could increase existing trends of bank armoring associated with more extensive riparian vegetation, including tamarisk. The Representative Preferred Alternative would also include lower releases, as low as 6.0 maf, which would result in similar impacts along the Colorado River as the other action alternatives but since these releases would result in more water flowing along Colorado River, the trends described above would be tempered. Lower releases also could limit the number of times an HFE could be triggered from Glen Canyon Dam; a trigger would only occur when the HFE furthers maintenance of target reservoir elevations.

The Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives would result in the greatest number of futures where HFEs are conducted. These lower flows may also result in the appearance of river features not visible under current conditions and less movement of the river's natural sandbars. If yearly elevations facilitate releases of 7.0 maf or more under the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives, the impacts under these alternatives would be similar to those described under the No Action Alternative and CCS Comparative Baseline as the lower releases from Glen Canyon Dam would be avoided. If the elevation

of Lake Powell were to drop below dead pool, flows from Glen Canyon Dam could dramatically decrease, resulting in impacts similar to those described under the No Action Alternative and CCS Comparative Baseline. For more information on the impacts on riparian vegetation, refer to **Section 3.9**, Vegetation Including Special Status Species; for impacts associated with sand bars, including their volume, refer to **Section 3.5**, Geomorphology and Sediment; and for impacts on recreation, including the visibility of river features, refer to **Section 3.14**, Recreation.

Issue 4: How would management of water availability for the Lower Division States affect landscape character?

Since the No Action Alternative would include minor (0.6 maf) adjustments to the distribution of water for Arizona and Nevada (but no adjustments for California) based on lowering Lake Mead elevations, there would initially be a limited incremental effect on irrigated landscapes, including those in agricultural use. If elevations in Lake Mead were to drop to dead pool (895 feet), flows from Lake Mead would dramatically decrease, resulting in lower water deliveries than currently allocated, affecting all three Lower Division States. As described in **Section 3.4**, Water Deliveries, the No Action Alternative would result in the most futures where dead pool–related reductions may be reached during the modeling period. Depending on the duration of these decreased water deliveries, the character of irrigated and agricultural landscapes within the Lower Division States would be modified through aridification of these areas; this would diminish the vivid greens associated with crops and ornamental plantings. The influence of the Colorado River on adjacent lands would narrow as these areas transition to their natural, arid condition. This would result in large-scale changes to the landscape character compared with the existing condition. The aridification of these lands could also result in more exposed soil, generating fugitive dust affecting visibility within the region, including from GCNP and other highly valued viewsheds. For more details on the impacts related to fugitive dust, please see **Section 3.7**, Air Quality.

The following alternatives all include shortages designed to avoid reaching dead pool, temper the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, and avoid more extensive impacts if Lake Mead reached dead pool. If Lake Mead reaches dead pool elevation during the planning period, impacts for all alternatives would be similar to those described under the No Action Alternative.

The CCS Comparative Baseline would include a series of water supply adjustments for the Lower Division States based on lower elevations of Lake Mead. If water levels in Lake Mead drop below 1,075 feet, effects similar to those described under the No Action Alternative would occur, with conservation measures tempering these effects. As Lake Mead approaches dead pool, to avoid a dramatic decrease in water releases from Hoover Dam affecting all three Lower Division States, more reductions (up to 1.38 maf) could occur. These reductions to avoid reaching dead pool would temper the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, as described under the No Action Alternative.

The Basic Coordination Alternative would have impacts similar to those under the No Action Alternative, as there would be adjustments to the distribution of water for Arizona and Nevada, but no adjustments for California, based on lowering Lake Mead elevations. As the Lake Mead elevation drops below 1,160 feet, shortages would begin; they would increase to 1.48 maf when Lake Mead is below 1,110 feet. Due to increased shortages under this alternative, the Basic Coordination Alternative

would result in the second most futures where dead pool–related reductions may be reached during the modeling period, as described in **Section 3.4**, Water Deliveries.

Under the Enhanced Coordination Alternative, there is a potential for greater shortages than under the No Action Alternative, CCS Comparative Baseline, and Basic Coordination Alternative, with shortages (up to 3.0 maf) being distributed pro rata among mainstream lower Colorado River water users independent of state. These shortages would occur in all three Lower Division States and incrementally affect irrigated landscapes, including those in agricultural use, based on the extent of the shortage. As described in **Section 3.4**, Water Deliveries, the Enhanced Coordination Alternative would result in the second least number of futures where dead pool–related reductions may be reached during the modeling period.

Under the Maximum Operational Flexibility Alternative, there is a potential for greater shortages than under the CCS Comparative Baseline and the Enhanced Coordination, No Action, and Basic Coordination Alternatives, with shortages being based on priority. These shortages would occur based on the total system effective storage and capacity, as described in Appendix S, **Section S.4.1.1**, Shortage Conditions, with shortages up to 4.0 maf. These shortages would occur in all three Lower Division States and incrementally affect irrigated landscapes, including those in agricultural use, based on the extent of the shortage. As described in **Section 3.4**, Water Deliveries, the Maximum Operational Flexibility Alternative would result in the least number of futures where dead pool–related reductions may be reached during the modeling period.

Under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), there is a potential for larger shortages (up to 2.1 maf) than under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, with shortages being distributed based on priority within a state or pro rata within that state as described in Appendix S, **Section S.5.1.1**, Shortage Conditions. If water levels in Lake Mead drop below 1,145 feet, effects similar to those described under the No Action Alternative are anticipated, with conservation measures tempering these effects. As lake levels continue to drop toward 1,000 feet, all three states would receive less water from the Colorado River under this alternative through proposed shortages, up to 2.1 maf, and conservation measures.

The Representative Preferred Alternative would result in shortages up to 3.0 maf, distributed based on Lower Basin consensus arrangements, if they exist, or otherwise distributed based on the priority system, with initial shortages beginning at 1.5 maf in 2027 and 2028. Consultation would occur if Lake Mead elevation were projected to be less than 1,000 feet to determine if additional reductions are needed in the Lower Basin (including Mexico). As described in **TA 4**, Water Deliveries, the Representative Preferred Alternative, similar to the Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, would be in the group of alternatives with the second-fewest futures involving dead pool–related reductions during the modeling period (Maximum Flexibility has the fewest futures). If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative. These results are within the range analyzed across the other alternatives.

For more information on the impacts on agricultural operations, refer to **Section 3.16**, Socioeconomics, and for more information on the specific, state-level water deliveries, refer to **Section 3.4**, Water Deliveries.

Summary Comparison of Alternatives

In general, alternatives that facilitate higher reservoir elevations, maintain higher flows along the Colorado River, including through Grand Canyon, and support full water deliveries to the Lower Division States would result in the lowest impacts on visual resources and landscape character. While some users may prefer lower lake levels in Lake Powell, to allow Cathedral in the Desert and other attraction features inundated by Lake Powell to be visible and accessible, in general higher water levels would result in lower impacts on landscape character because there would be shorter calcium carbonate rings, less exposed shoreline (including trash and other debris), and smaller sediment deltas.

During wet hydrologic conditions, the range of alternatives would generally produce conditions where lake levels and flows along the Colorado River would result in minimal impacts on landscape character.

Under drier conditions, the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives would facilitate more futures with higher reservoir elevations and lower flows along the Colorado River to minimize the risk of reaching dead pool. These alternatives also include larger water delivery shortages to the Lower Division States, which were designed to avoid reaching dead pool. These alternatives would result in shortages up to 3.0 maf and 4.0 maf, depending on the alternative, which would incrementally affect irrigated landscapes, including those in agricultural use, as shortages occur.

The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would result in the most futures where landscape character is affected by lower water levels in Lake Powell and higher flows along the Colorado River, which would increase the risk of reaching dead pool. Based on management to keep water levels higher in Lake Mead than Lake Powell, under the Basic Coordination Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), impacts associated with lower Lake Mead reservoir levels would be reduced and impacts would be similar to those under the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives.

The CCS Comparative Baseline and the No Action and Basic Coordination Alternatives would include smaller shortages in water deliveries to the Lower Division States—0.6 maf, 1.38 maf, and 1.48 maf, respectively—resulting in limited initial effects on irrigated landscapes compared with the Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternative. If dead pool is reached, however, the character of irrigated and agricultural landscapes within the Lower Division States would be more dramatically modified through aridification of agricultural and other irrigated landscapes. The Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, Supply Driven Alternative, and Representative Preferred Alternative would result in the least number of futures, with Maximum Operational Flexibility resulting in the fewest, where dead pool-related reductions may be reached during the planning period.

Chapter 4. Consultation and Coordination

4.1 Introduction

This chapter summarizes the consultation and coordination between Reclamation and specific federal, state, and local agencies, tribes, and the general public, during the preparation of this Final EIS. A detailed listing of coordination and consultation efforts with Basin Tribes is provided in **Appendix P**, Tribal Consultation and Coordination Efforts.

4.2 General Public Involvement Activities

The public involvement process leading to this Final EIS included a "pre-scoping" effort, scoping, consultation, and coordination with Basin Tribes, Basin States, federal and state agencies, water users, water conservation districts, non-governmental organizations (NGOs), other interested stakeholders, and the public. Reclamation developed and implemented a public involvement plan to satisfy the public participation requirements set forth in NEPA and to establish a consistent and constant level of engagement with interested parties and stakeholders. The multifaceted approach consisted of informational materials, consultation and coordination meetings, general and stakeholder outreach, and media relations.

A variety of informational materials were used to educate and inform audiences about the process and related issues. A website was established and maintained for this EIS process. It contains project documents, points of contact, and recordings of public meetings. An electronic mailing list was used to notify interested parties of website postings, project meetings, and documents. A project email account was maintained throughout the preparation of this Final EIS for interested parties to express opinions, ask questions, and submit comments.

Reclamation discussed the development of the proposed federal action with various agencies and organizations at: (1) agency/organization regular meetings; (2) public conferences and events sponsored by the agencies/organizations; and (3) meetings sponsored by Reclamation. The entities included the Basin States' water resource departments, water agencies within these states, contractors and associations for federal hydroelectric power, and NGOs. Reclamation also consulted with Indian tribes and Mexico.

A synopsis of the NEPA-related outreach efforts for this EIS follows:

Before formally initiating the NEPA process, in June 2022, Reclamation conducted a public "pre-scoping" effort requesting input on suggested mechanisms to ensure a wide range of stakeholder participation in the process and potential substantive elements to be considered for post-2026

operations.[1] Using the input received, on June 16, 2023, Reclamation published an NOI to prepare an EIS in the *Federal Register* (88 *Federal Register* 39455), formally initiating the public scoping process. Reclamation notified interested parties of the NOI and scoping comment period through an email notification to the project mailing list on June 16, 2023. Over the 60-day scoping period, Reclamation engaged with stakeholders through public webinars, tribal consultations, and technical education sessions.

Reclamation held three virtual public webinars during the scoping period. One meeting was attended by 185 people on July 17, 2023, from 1:00 p.m. to 2:00 p.m. mountain daylight time. The second virtual public meeting was attended by 112 people on July 18, 2023, from 10:00 a.m. to 11:00 a.m. mountain daylight time. The third virtual public meeting was attended by 66 people on July 24, 2023, from 6:00 p.m. to 7:00 p.m. mountain daylight time. The webinars included an opening statement, a presentation that summarized the NOI, a range of hydrologic and operational scenarios that informed people about the EIS analysis, an overview of potential alternatives being considered in the EIS, information on the EIS process schedule, and a question-and-answer session. The webinars were recorded and published on the project website. Public comments were accepted during the comment period by email and mail. Reclamation received a total of 24,290 comment letters from a wide range of interested parties, including federal, state, and local entities; tribes; NGOs; other stakeholder groups; and individuals. A Notice of Availability (NOA) for the Scoping Report (Reclamation 2023b) was published in October 2023 in the *Federal Register* (88 *Federal Register* 72535), summarizing all public comments received during the scoping period.

On January 16, 2026, the EPA published a Notice of Availability in the Federal Register for the Draft EIS. This kicked off a 45-day public review and comment period that ended on March 2, 2026. Reclamation hosted two virtual public meetings on January 29, 2026, and February 10, 2026. These meetings were held to provide information on the Draft EIS and answer clarifying questions; public comments were not heard during the meetings. Each meeting presented the same information. The question-and-answer portions of the meetings varied based on the public participants at each meeting. The webinars were recorded and published on the project website. A detailed overview of the public review process and comments received is provided in the Response to Public Comments (**Appendix R**).

4.3 Cooperating Agency Involvement

In compliance with NEPA, Reclamation worked with five cooperating agencies in the preparation of this EIS. As described in **Chapter 1**, cooperating agencies included the BIA, NPS, FWS, USIBWC, and WAPA. In developing the Final EIS, Reclamation hosted bi-weekly cooperating agency virtual

[1] The pre-scoping period began with a Federal Register notice on June 24, 2022 (87 *Federal Register* 37884). The Department received substantial feedback from partners, stakeholders and the public which Reclamation summarized in a Pre-Scoping Summary Report (Reclamation 2023a).

meetings to obtain data, information, resource analysis, and review internal documents. Additionally, individual agencies provided specific assistance, including the following:

- The BIA administers the federal trust responsibility to Indian tribes.
- Given its jurisdiction of NPS units within the Basin and administration of recreation on Lake Powell and Lake Mead, the NPS provided data and analysis of potential impacts on resources under its management.
- The FWS has jurisdiction by law and special expertise with respect to the ESA and biological resources within the study area and its administration of several National Wildlife Refuges in the study area. The FWS is providing resource expertise and is working closely with Reclamation in developing biological assessments to support consultation under Section 7 and Section 10 of the ESA.
- The USIBWC provided guidance and reviewed internal documents to ensure the EIS adequately addressed treaty obligations and international commitments. The USIBWC has worked with Reclamation to ensure that Mexico has been kept informed of all permissibly available information regarding the EIS process.
- The WAPA provided hourly release volume models for Glen Canyon Dam to aid in resource-specific modeling. The WAPA also provided hydroelectric modeling to assess impacts on power generation and revenue across the major generation facilities in the Upper and Lower Basins.

While not a cooperating agency, the USGS also contributed extensive expertise and resource modeling support.

4.4 Tribal Consultation and Coordination

For purposes of this NEPA process, Reclamation is consulting and coordinating with Basin Tribes who have entitlements to or contracts for Colorado River water and those that may be affected by or have interests in the proposed federal action. Tribes provided Reclamation with written comments on the proposed federal action and its potential effects on resources of tribal concern, including Indian trust assets. Reclamation's tribal engagement strategy was comprised of three approaches to tribal coordination and consultation: 1) Reclamation-hosted monthly virtual meetings for all Basin Tribes where updates on the process were provided, 2) regularly attending tribal meetings upon request and invite, including group meetings such as the Ten Tribes Partnership or the Inter-Tribal Council of Arizona, and 3) engaging in and initiating government-to-government consultations. In addition, Reclamation convened a group of interested Basin Tribes throughout 2024 and 2025 to discuss proposed management strategies and review modeling results, which ultimately informed the development of the Enhanced Coordination Alternative. Reclamation has provided the Basin Tribes with technical support during these discussions by modeling various strategies, including protection of key elevations of Lake Powell and Lake Mead. A detailed listing of coordination and consultation efforts with Basin Tribes is provided in **Appendix P**, Tribal Consultation and Coordination Efforts.

4.5 Endangered Species Act Consultation

Reclamation and FWS have historically consulted on Lower Basin and Upper Basin Colorado River operations separately and in alignment with effects related to operations at Glen Canyon Dam, including Lake Powell, and Hoover Dam, including Lake Mead. A Biological Assessment for annual releases from Glen Canyon Dam was completed in the summer of 2026, and a Biological Opinion is anticipated to be issued subsequently. This Biological Opinion will replace the existing 2007 and subsequent 2024 Interim Guidelines Biological Opinions (FWS 2007, 2024); the 2016 Glen Canyon Dam LTEMP Biological Opinion (FWS 2016), which considers monthly, daily, and hourly release volumes, will remain in effect. Section 7 consultations for current and future operations from Lake Mead to the SIB with Mexico were conducted in 2005, 2018, 2022, and 2024, and those Biological Opinions will cover implementation of the ROD for those reaches (FWS 2005, 2018, 2022, 2024). These Biological Opinions provide incidental take analysis and coverage for specific reductions in flow associated with defined operational conditions. The 2024 Biological Opinion provides incidental take analysis and coverage for reductions in flow of up to 3.0 maf from Lake Mead through January 31, 2028, encompassing operations within that timeframe, including anticipated 2027 operations, provided they remain within the analyzed operational conditions. An amendment to the LCR MSCP Habitat Conservation Plan and an associated Biological Assessment are currently being developed, with an anticipated completion in January 2028, to extend Section 7 and Section 10 consultation incidental take coverage for the LCR MSCP's Federal and non-Federal parties until 2055.

4.6 State and Local Water and Power Agency Coordination

Since the June 13, 2023 *Federal Register* notice announcing Reclamation's interest in soliciting comments on the development of the Post-2026 EIS, Reclamation has had various discussions with state and local water agencies regarding the proposed federal action. However, the Basin States have been continuously engaged in drought mitigation discussions related to post-2026 operations since the adoption of the 2019 DCPs. Reclamation has provided the Basin States technical support during these discussions by modeling various strategies, including protection of key elevations of Lake Powell and Lake Mead.

As they did for the 2007 Interim Guidelines NEPA process, the Basin States informed the projections of future depletions of Colorado River water anticipated in each State for this Post-2026 process. The Upper Colorado River Commission compiled Upper Basin depletions and submitted them to Reclamation, and Reclamation consulted with the Lower Division States regarding their respective depletions. These projections were used as input to Reclamation's operational modeling analysis, as discussed in this EIS.

The Upper Division States and Lower Division States each submitted proposals for alternatives to be considered in the Draft EIS in the spring of 2024. The Upper Division States submitted a revised proposal in December 2024, and the Lower Division States submitted a revised proposal in January 2025. Reclamation worked extensively with the Basin States to not only understand and gather additional information, but also to model and perform detailed preliminary analyses of their original and revised proposals. Reclamation discussed these results and potential refinements on numerous occasions with the Basin States prior to releasing the Draft EIS.

During the Draft EIS public comment period, Reclamation received individual comments from each of the seven Basin States, including proposed operational strategies. Subsequently, in May 2026, both the Upper Division States and Lower Division States submitted additional proposals. Throughout spring and summer 2026, Reclamation and the Department have engaged extensively with the Basin States to facilitate alignment among all seven states and the Secretary on key aspects of post-2026 operations for consideration in this NEPA process.

4.7 Non-Government Organizations

Reclamation contacted and coordinated the preparation of this Final EIS with multiple recreational and environmental groups. A consortium of environmental organizations that included the National Audubon Society, Western Resource Advocates, Theodore Roosevelt Conservation Partnership, American Rivers, The Nature Conservancy, Environmental Defense Fund, and Trout Unlimited developed what became the Maximum Operational Flexibility Alternative analyzed in this Final EIS. This consortium of environmental organizations developed and submitted its first proposal, "Cooperative Conservation Alternative," on March 29, 2024. As with the Upper Division and Lower Division States proposals, Reclamation worked extensively with these organizations to not only understand and gather additional information, but also to model and perform detailed preliminary analyses of their proposal. From 2024 through 2025, Reclamation met with representatives of the consortium of environmental organizations and worked with them to formulate what became the Maximum Operational Flexibility Alternative, as analyzed herein.

4.8 Other Consultations

Per Section 106 of the NHPA and its implementing regulations (36 CFR 800), Reclamation is consulting with the Arizona, California, Nevada, and Utah SHPOs; THPOs; affected tribes without THPOs; and consulting parties regarding the effects of the undertaking on historic properties. Reclamation developed a project specific programmatic agreement, in consultation with the SHPOs, THPOs, tribes without THPOs, cooperating agencies, and other consulting parties per 36 CFR 800.14 to outline a process to resolve any adverse effect on historic properties from Reclamation's operation of the Glen Canyon and Hoover Dams under the new operating guidelines for annual releases.

4.9 Consultations with the Government of Mexico Agencies

The USIBWC has engaged in consultation with agencies of Mexico regarding the proposed federal action and development of a new Minute to the 1944 Water Treaty. Reclamation has assisted USIBWC in conducting this consultation by providing information on the proposed federal action and by participating in briefings with the Mexican Section of the IBWC, the Mexico National Water Commission, and Mexico Secretariat of Foreign Relations. Consistent with these consultations, Section 397 of Public Law 109-432 directs Reclamation to use these treaty-related processes to identify potential impacts beyond the borders of the U.S. Accordingly, meetings with representatives of Mexico were conducted, during which representatives of Mexico provided their views, input, and concerns regarding the potential effects of the proposed federal action.

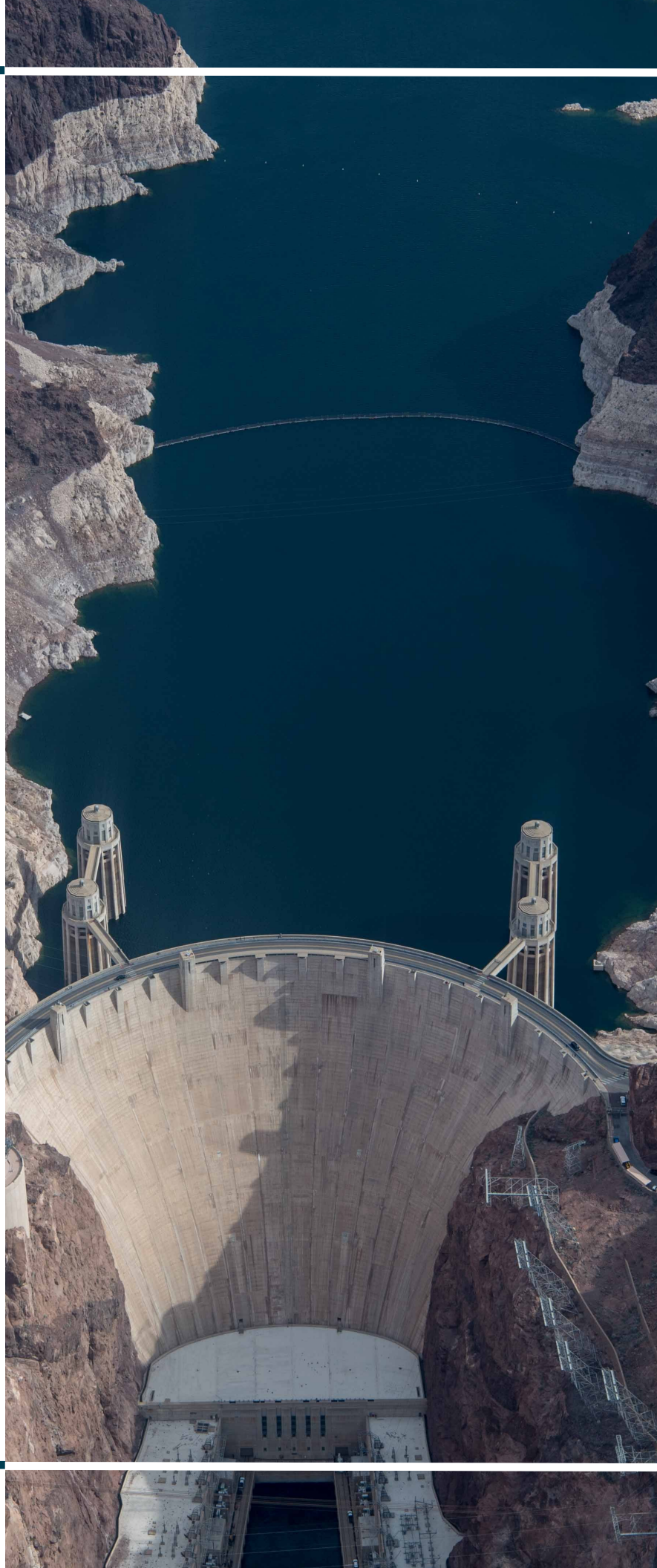
This Final EIS documents the hydrologic and water quality effects of the proposed federal action on water deliveries to Mexico (see **Chapter 3** and **Appendix N**, International Border Region of the Colorado River). Reclamation's modeling assumptions in this Final EIS are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

BUREAU OF
RECLAMATION

Final Environmental Impact Statement

Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

Volume II: Supporting Appendices



July 2026
U.S. Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Basins
Interior Regions 7 and 8

BUREAU OF
RECLAMATION

Mission Statements

The **Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo: Alexander Stephens / Bureau of Reclamation, 2018

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Appendix A

CRSS Model Documentation

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A1 CRSS Lake Powell Assumed Monthly Releases
A2 CRSS Lower Division State Water User Priorities

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Acronyms and Abbreviations

	Full Phrase
1944 Water Treaty	United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2006 Flaming Gorge ROD	2006 Record of Decision for the Operation of Flaming Gorge Dam Final Environmental Impact Statement
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2012 Aspinall ROD	2012 Record of Decision for the Aspinall Unit Operations Final Environmental Impact Statement
af	acre-feet
Basin	Colorado River Basin
BWSCP	Binational Water Scarcity Contingency Plan
CAP	Central Arizona Project
CCS	Continued Current Strategies
cfs	cubic feet per second
CRSP	Colorado River Storage Project
CRSS	Colorado River Simulation System
CVWD	Coachella Valley Water District
DCP	Drought Contingency Plan
EIS	environmental impact statement
EOCY	end of calendar year
EOWY	end of water year
EOWYST	end of water year storage target
IBWC	International Boundary and Water Commission
ICS	Intentionally Created Surplus
kaf	thousand acre-feet
Lower Basin	Lower Colorado River Basin
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
Mexico	United Mexican States
MWD	Metropolitan Water District

NIB	Northerly International Boundary
NIIP	Navajo Indian Irrigation Project
PIP	Powell infrastructure protection
PPR	present perfected right
Reclamation	Bureau of Reclamation
SNWA	Southern Nevada Water Authority
TMD	transmountain diversion
UIU	Upper Initial Unit
Upper Basin	Upper Colorado River Basin
U.S.	United States
USACE	United States Army Corps of Engineers

Appendix A. CRSS Model Documentation

A.1 Background

The Colorado River Simulation System (CRSS), developed by the Bureau of Reclamation (Reclamation) in the 1980s, has long been a foundational tool for long-term policy and planning studies on the Colorado River. Initially built in Fortran and run on a Cyber mainframe, the original CRSS modeled twelve major reservoirs and approximately 115 aggregate diversion points across the Upper Colorado River Basin (Upper Basin) and Lower Colorado River Basin (Lower Basin) on a monthly time step. However, a key limitation of the Fortran-based CRSS was that the operating policies or rules were hardwired into the modeling code, making modification of those policies difficult.

To address emerging needs of the Interim Surplus Criteria Environmental Impact Statement (EIS) in the early 1990s, particularly for surplus and shortage studies in the Lower Basin, Reclamation created CRSSez, a simplified annual time step model implemented in Visual Basic (Bureau of Reclamation 1998). This model focused on Lake Powell and Lake Mead, simplifying upstream and downstream systems.

In 1994, Reclamation partnered with the University of Colorado and the Tennessee Valley Authority to develop RiverWare™, a more flexible and general-purpose modeling tool. Unlike its predecessors, RiverWare™ allowed users to define and prioritize operational rules through a graphical interface, enabling more dynamic and efficient scenario analysis (Zagona et al. 2001). By 1996, CRSS was fully transitioned into RiverWare™, maintaining the original model's structure and data while allowing for more adaptable rule sets.

Since then, CRSS has continued to evolve, with new rule sets developed to reflect current policies and improvements made to physical process methodologies. In 2005, CRSS-Lite was introduced as a faster, more efficient alternative to CRSSez, built within RiverWare™. It retained the complexity and accuracy of CRSS while significantly reducing execution time, making it a valuable tool for evaluating a wide range of operational strategies in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 Final EIS).

In the 2010s, CRSS was used in various studies to identify current and future imbalances in water supply and demand across the Colorado River Basin (Basin) as part of the Colorado River Basin Water Supply and Demand Study and Tribal Water Study. CRSS also facilitated decision-making during the negotiation of the 2019 Drought Contingency Plan (DCP) and Minute 323 in 2017.

In 2023, Reclamation revised CRSS to reduce model bias and better characterize the variability and range of Upper Basin depletions. To address these issues, the updated model includes "not pre-

shorted" Upper Basin demands (rather than "pre-shorted" demands), as well as logic that limits the natural flow available for diversion by the Upper Basin agricultural water users by calibrating to historical Upper Basin gage records. This effort also included adding three new Upper Basin reservoirs to better model exports from the Basin and to more accurately model the seasonal timing of tributary water use. This version of CRSS – deemed CRSS version 6 – served as the baseline model used for this Final EIS.

A.2 Overview

CRSS simulates the operation of the major reservoirs on the Colorado River system and provides information regarding the projected future state of the system on a monthly basis. CRSS models 15 reservoirs, as shown in **Map A-1**, and approximately 359 water users aggregated on 184 modeled diversions (demands and return flows). The model is initialized on December 31, 2026, and run for 34 years, simulating conditions through December 31, 2060. Output variables include the volume of water in storage, reservoir elevations, releases from the dams, energy generation, streamflow, and diversions to and return flows from water users throughout the system.

CRSS requires a broad range of input data. Modeled reservoirs require physical parameters such as individual storage capacity, evaporation rates, bank storage, and release capabilities. Storage capacity and evaporation rates are derived from reservoir-specific studies or pan evaporation-based estimates, and Reclamation continues to fund work to improve these inputs. Reservoir evaporation assumptions and parameters are summarized in **Section A.10**. Other inputs include initial reservoir conditions (**Appendix G**), demand schedules for entities in the Upper Division States (**Appendix L**), Lower Division States (**Appendix M**) and the United Mexican States (Mexico), and future hydrologic natural flows at 29 locations (**Section A.3** and **Appendix F**). This appendix focuses on the assumptions regarding reservoir operations, particularly at Lake Powell and Lake Mead, as those vary by alternative, and other physical process calculations in CRSS (energy generation and salinity). Additional modeling assumptions had to be developed to model the storage and delivery mechanisms for conserved water and are included in **Appendix B**.

A.2.1 Model Uncertainty

CRSS projections are subject to multiple sources of uncertainty. One source is the model, which is a simplified representation of a complex system. Another component of uncertainty is the need to estimate physical processes, such as reservoir evaporation and transpiration from plants. The most impactful source of uncertainty is the future itself; models rely on assumptions about how the hydrology, water demand, and policy and operations will unfold. Reclamation works with stakeholders and scientists to develop the best modeling practices and most appropriate assumptions in light of the purpose of the model. It is important to understand the purpose, approach, and assumptions associated with projections and their inherent uncertainty to properly interpret the information they provide. Within this context, CRSS remains the most suitable and robust tool available for the comparative purposes of this Final EIS.

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Map A-1
CRSS Modeled Reservoirs



Reservoir modeled in CRSS

Colorado River

Major Colorado River tributary

Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

The TMD Reservoir was excluded because it represents an aggregation of Colorado western slope transmountain diversion storage facilities, including Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoir.

Projections are most sensitive to assumptions about future hydrology, and future flows are highly uncertain. Assumptions about future hydrology can produce very different pictures of risk. To address this challenge, the EIS applies a Decision Making under Deep Uncertainty framework, described in **Appendix E**, which enables evaluation of outcomes across a wide range of plausible future hydrologic conditions.

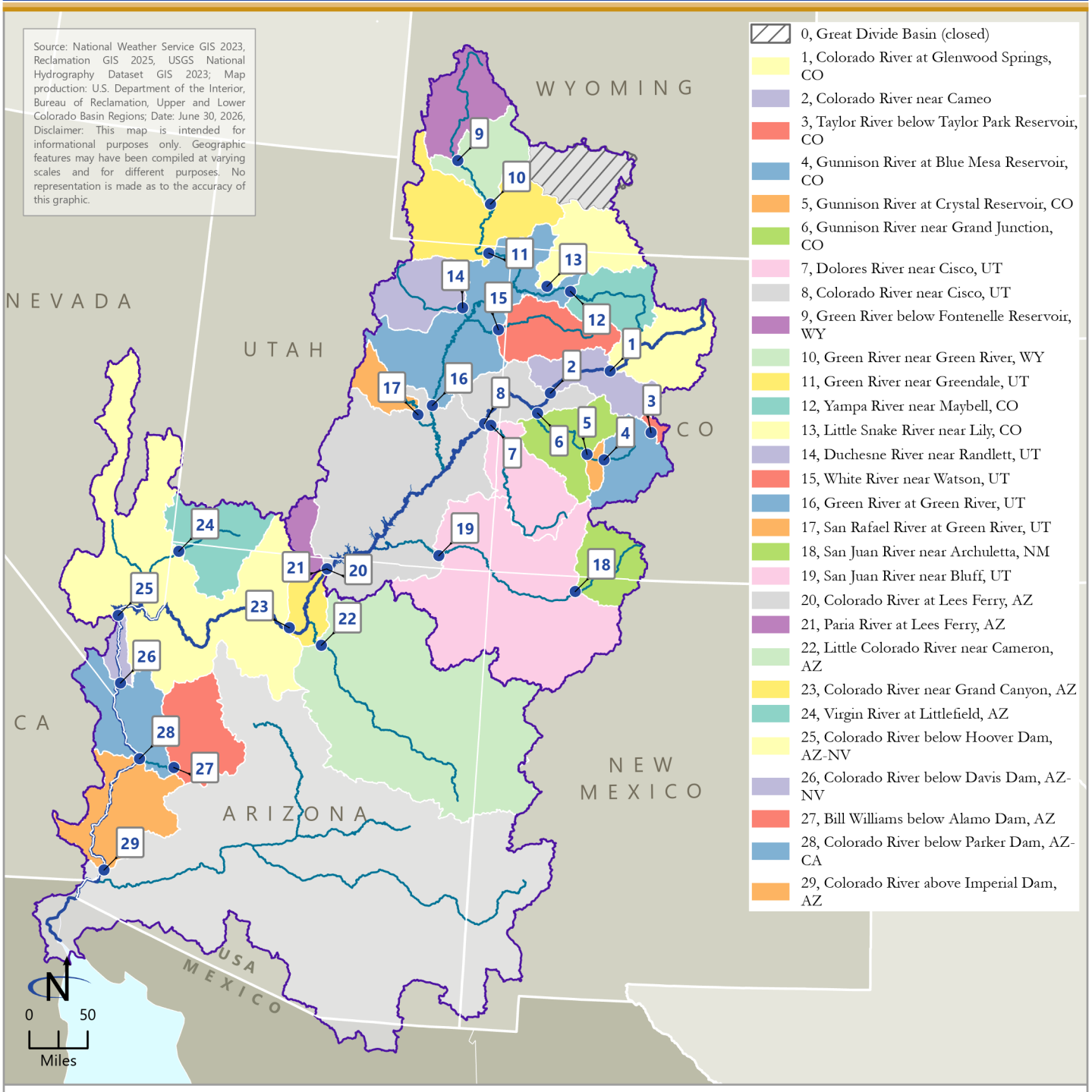
A.3 Hydrology

Hydrology inputs to CRSS are natural flows, which are the flows that would have been observed at a stream gage adjusted to remove the effects of upstream reservoirs and depletions. There are 21 Upper Basin natural flow points and 8 Lower Basin natural flow points as shown in **Map A-2**. The historical natural flow record was developed using the method published in Prairie and Callejo (2005). Historical natural flows are computed using streamflow gauges, reservoir regulation, reservoir evaporation losses, and water use from the Upper Basin Consumptive Use and Loss reports (Reclamation 2022) and Lower Basin Water Accounting Reports (Reclamation 2023). The natural flows include gains and losses from natural process such as gains from tributaries, seepage, transit losses, and riparian evapotranspiration along the river corridor. Starting with the release of the 1906-2020 natural flows in December 2022, the Lower Basin phreatophyte losses are no longer explicitly modeled in the development of natural flows. As such, these losses are now reflected in the computed intervening natural flows in the three reaches downstream of Hoover Dam.

There are several methods for projecting possible future natural flow sequences or hydrology scenarios for the 29 natural flow points in CRSS. Because CRSS is a long-term model capable of projecting decades into the future, hydrologic inputs are derived from methods designed to represent future uncertainty in hydrologic variability and long-term change. These methods include resampling the historical record (either from the measured record or a derived record using a "proxy" such as tree-ring data), deriving future inflow data by preserving key statistics from the historical record while adding a random component, and using physically based hydrology models to simulate runoff based on general circulation model projections of temperature and precipitation. Reclamation chose 400 unique hydrologic sequences, or traces, to run through CRSS for the purposes of this Final EIS to explore basin conditions under a broad range of flow characteristics and patterns. For more information about these traces and how they were selected, see **Appendix F**.

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Map A-2
Colorado River Natural Flow Basins



A.3.1 Glen Canyon Dam to Lees Ferry Accretion Flows

Geographically, the Lees Ferry subbasin (**Map A-2**) encompasses areas both upstream and downstream of Glen Canyon Dam, with the Lees Ferry gage serving as the downstream boundary. In CRSS, the Lees Ferry intervening natural flow is split such that a portion of the estimated gains and losses is introduced into the model above Glen Canyon Dam and a portion is introduced below it. The portion of the flow added to the reach below Glen Canyon Dam follows a monthly pattern based on historical data as shown in **Table A-1**, while the remaining portion of the Lees Ferry intervening natural flow is introduced to the reach above Glen Canyon Dam. The data in **Table A-1** are derived from the average difference between the Lees Ferry gaged flow and the Glen Canyon Dam releases from 2006 through 2021. Using this distribution, approximately 70 percent of the Lees Ferry intervening natural flow occurs above Lake Powell, with the remaining 30 percent below Glen Canyon Dam.

Table A-1
Gains & Losses for the Glen Canyon Dam to Lees Ferry Reach

Month	Average Gains & Losses (acre-feet [af])
January	11,200
February	8,800
March	9,700
April	12,200
May	13,100
June	13,500
July	19,400
August	19,100
September	14,300
October	11,300
November	6,000
December	7,900

A.4 Initial Reservoir Conditions

CRSS was initialized using a single set of reservoir conditions projected for December 31, 2026. The initial conditions are described in **Appendix G**.

The changes in volume of water storage in all reservoirs are calculated by CRSS using relationship curves that are programmed into the model. These relationship curves relate the water surface elevation to live capacity, total capacity, and surface area for each respective reservoir. The latest available curves for Lake Powell and Lake Mead are available in Bradley and Collins (2022) and Reclamation (2011), respectively. The assumed maximum capacity of reservoirs that are used in one or more alternatives to determine Lake Powell or Lake Mead operations is provided in **Table A-2.**

Table A-2
Assumed Maximum Reservoir Storage from CRSS

Reservoir	Maximum Storage (1000 acre-ft)
Flaming Gorge	3,671
Blue Mesa	828
Navajo	1,648
Lake Powell	23,314
Lake Mead*	26,120
Lake Mohave	1,810
Lake Havasu	619

*Excluding 1.5 million acre-feet (maf) exclusive flood control space.

A.5 Operations Upstream of Lake Powell

In CRSS, 12 Upper Basin reservoirs and 222 Upper Basin water users are modeled. Upper Basin water users are distributed among the tributaries of the Upper Basin and aggregated by use sector. These sectors include agriculture, energy, environment, reservoir evaporation, exports, lease, municipal and industrial, and minerals. Each water user has a corresponding diversion and depletion schedule input into CRSS (see **Appendix L**). To achieve the full scheduled depletion, sufficient natural flow must be available within the corresponding reach to meet all scheduled diversions. When available natural flow is not available, users are unable to meet their "not pre-shorted" depletion schedules.

Upper Basin reservoirs modeled operations are consistent with their individual operation plans. Some facilities are operated to meet storage or elevation targets, while others feature environmentally regulated, controlled, consistent releases. Within the model, each reservoir has a set of rules to guide the specific operations. The model solves by using the logic in those operating rules. The following briefly describes the various Upper Basin reservoirs along with a high-level description of the logic in RiverWare™ for simulating operations within the Upper Basin. The operations of the Upper Basin reservoirs above Lake Powell are modeled the same for all alternatives except during Lake Powell infrastructure protection (PIP) releases (**Section A.5.11**).

In a rule-based model, general assumptions must be made for the model to solve. The rules developed for CRSS are, ideally, the best representation of operations that can be projected. In practice, however, there are sometimes differences between the projected operations produced by the model and actual operations. For example, many reservoirs in the Upper Basin are operated following the principles of adaptive management. As such, operations may be altered to meet various objectives of the reservoirs' adaptive management work groups on an ad hoc or

experimental basis. Such ad hoc or experimental operations cannot be known in advance. As such, CRSS projections may differ from actual operations, even under similar hydrologic conditions.[1]

A.5.1 Available Water to Upper Basin Agricultural Water Users

Upper Basin agricultural water users are subject to limits on the natural flow available for diversion. CRSS applies a "percent available" factor, which represents that only a limited volume of natural flow is available to users on high tributaries that are not explicitly modeled. The "percent available" factors are calibrated in each reach to minimize streamflow bias at gaged locations during the historical verification period (2000 through 2024). In reaches where modeled streamflow underestimates observed flows (i.e., exhibits a negative bias), calibration reduces the percentage of natural flow available for diversion. This adjustment decreases depletions, increases modeled Upper Basin shortages and streamflow, and thereby reduces bias between modeled and historical streamflow.

A.5.2 Fontenelle Reservoir

Fontenelle Reservoir is on the Green River about 24 miles southeast of La Barge, Wyoming. Fontenelle Reservoir is operated to meet various target elevations throughout the year while staying within practical and authorized limits.

A.5.3 Flaming Gorge Reservoir

Flaming Gorge Reservoir is on the Green River about 32 miles downstream of the Utah-Wyoming border and upstream of the confluence with the Yampa River. The operations of Flaming Gorge Reservoir meet the requirements detailed in the 2006 Record of Decision for the Operation of Flaming Gorge Dam Final EIS (2006 Flaming Gorge ROD; Reclamation 2006a) that were designed to achieve the authorized purposes of the Colorado River Storage Project Act, while addressing environmental requirements. The 2006 Flaming Gorge ROD outlines the operational guidelines of Flaming Gorge and implements, to the extent possible, recommendations to assist in the recovery of four endangered fish species, outlined in the 2000 Flow and Temperature Recommendations for Endangered Fish in the Green River Downstream of Flaming Gorge Dam (Muth et al. 2000).

Flaming Gorge operations are governed by the April through July unregulated inflow into the reservoir, which determines the corresponding hydrologic classification, spring peak, and base flow targets from the 2006 Flaming Gorge ROD (Reclamation 2006a) for the year. The April through July releases are modeled at the daily time step in CRSS to approximate the sub-monthly component of the spring peak targets. The model logic determines typical daily operations from April through July before summing up to a monthly release. During the March to April transition period, Flaming Gorge operations try to achieve a May 1 storage target (upper limit drawdown elevation). Actual annual operations at Flaming Gorge are determined in a consultation process with other agencies.

[1] The UIU elevations reflected in this appendix are provided for National Environmental Policy Act analysis purposes only and do not reflect a federal position on what operations are appropriate or possible at low reservoir elevations. At Flaming Gorge, for example, operations that approach the low elevations described would likely reflect emergency operations where there is enough water remaining in Flaming Gorge for approximately one year of operations above minimum operating levels. Flaming Gorge operations at such low levels are likely inappropriate for non-emergency operations.

CRSS cannot model these adaptive management decisions; therefore, model results do not include possible future adaptive management decision changes to the logic described above.

A.5.4 Strawberry Reservoir

Strawberry Reservoir is located in central Utah and is the terminal reservoir of the Strawberry Aqueduct and Collection System, which is part of the Central Utah Project. Releases from Strawberry Reservoir operate to meet downstream flow targets and storage objectives. Diversions from the reservoir are made to the Utah Lake System based on the available volume in storage. Diversions are adjusted when Strawberry Reservoir's pool elevation is greater than 7,576.34 feet. Flood control releases are made from March through October if the storage exceeds 1.02 million acre-feet (maf).

A.5.5 Starvation Reservoir

Starvation Reservoir is on the Strawberry River downstream of Strawberry Reservoir near Duchesne, Utah. Releases from Starvation Reservoir are set based on monthly flow targets and flood control operations. Flood control releases are made from March through October if the storage exceeds 165 thousand acre-feet (kaf).

A.5.6 TMD Reservoir

The TMD Reservoir is an aggregate representation of Colorado western slope transmountain diversion (TMD) storage facilities, including Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoir. TMD Reservoir storage varies monthly based on hydrologic conditions and is reduced when downstream senior water rights, such as the Shoshone Powerplant or Grand Valley, experience shortages. Diversions from the TMD Reservoir are adjusted according to natural flow conditions, decreasing when supplies are abundant and increasing when they are limited. Outflows occur when the reservoir nears capacity and must release excess water. These modeled outflows are not meant to directly represent operations at the individual reservoirs.

A.5.7 Taylor Park Reservoir

Taylor Park Reservoir is on the Taylor River, a tributary of the Gunnison River on the western slope of Colorado's Rocky Mountains. Taylor Park Reservoir is operated with a rule curve to meet various target elevations throughout the year, while staying within practical and authorized limits.

A.5.8 Aspinall Unit Reservoirs – Blue Mesa, Morrow Point, and Crystal

The Aspinall Unit consists of three reservoirs—Blue Mesa, Morrow Point, and Crystal—in series along the Gunnison River in western Colorado. The operations of the Aspinall Unit meet the requirements detailed in the April 2012 Record of Decision for the Aspinall Unit Operations Final EIS (2012 Aspinall ROD; Reclamation 2012) and the decree quantifying the Federal Reserved Water Right for the Black Canyon of the Gunnison, which specify the spring peak outflow hydrographs and base flows for the rest of the year based on the hydrologic conditions upstream of Blue Mesa Reservoir. The 2012 Aspinall ROD provides specifications to avoid jeopardizing the continued existence of fish listed under the Endangered Species Act and to ensure the dam's operations do not result in the destruction or adverse modification of critical habitat in the Gunnison River.

Aspinall Unit operations are governed by the April through July unregulated inflow into the reservoir, which determines spring peak and base flow targets for the rest of the year based on the hydrologic conditions above Blue Mesa Reservoir. CRSS approximates daily flow targets in the 2012 Aspinall ROD and Federal Reserved Water Right for the Black Canyon of the Gunnison by first modeling typical daily operations for both the spring and baseflow periods and then summing to a monthly release. Morrow Point and Crystal Reservoirs are modeled to maintain elevation targets of 7,153.73 and 6,753.04 feet, respectively.

A.5.9 McPhee Reservoir

McPhee Reservoir is the primary storage facility of the Dolores Project, located on the Dolores River in southwestern Colorado. Inflows to the McPhee Reservoir are derived from the Cisco-Dolores natural flow with volumes split between the Dolores River and McPhee Reservoir based on hydrologic conditions. An environmental pool is tracked in McPhee Reservoir and can be used to meet target monthly environmental releases. The environmental pool is reset every October to the minimum of either 13 percent of the previous month's storage or the maximum environmental pool capacity of 29,300 acre-feet (af). Water stored in McPhee Reservoir is primarily used to meet the demands of the Dolores Project, with inflows used first and stored water, excluding the environmental pool, used when inflows are insufficient.

A.5.10 Navajo Reservoir

Navajo Reservoir is on the San Juan River above the confluence with the Animas River. The reservoir is operated to meet environmental requirements outlined in the July 2006 Record of Decision for the Navajo Reservoir Operations, Navajo Unit-San Juan River New Mexico, Colorado, Utah Final EIS (Reclamation 2006b). Navajo Reservoir also provides for the diversion of Navajo Indian Irrigation Project (NIIP) water from Navajo Reservoir, and other municipal and industrial uses throughout the San Juan Basin. The minimum active storage at Navajo Reservoir is at 5,990 feet; at that point, the NIIP can no longer divert water.

Navajo Reservoir operations are modeled to first meet the environmental baseflow requirements at downstream gages stated in the July 2006 Record of Decision for the Navajo Reservoir Operations, Navajo Unit-San Juan River New Mexico, Colorado, Utah Final EIS (Reclamation 2006b); because of the CRSS spatial scale, it is assumed that all flow targets are for the San Juan River near Bluff, New Mexico. If available additional water is released as a spring peak, a spring release pattern is selected to bring Navajo Reservoir closest to the September 30 storage target, while staying within practical and authorized limits, including maintaining NIIP diversions. If the reservoir pool elevation is projected to go below 5,990 feet, the minimum elevation for NIIP diversions, the outflow, and NIIP diversions are proportionally reduced.

A.5.11 Powell Infrastructure Protection Releases

PIP releases are modeled as releases from Upper Initial Units (UIUs) under low elevation conditions at Lake Powell in the Continued Current Strategies (CCS) Comparative Baseline, Basic Coordination Alternative, and Supply Driven Alternative. The PIP release modeling assumptions are simplifications of the actual PIP process, which, like the Drought Response Operations Agreement, involves collaborative decision-making among stakeholder workgroups and includes subjective judgments that cannot be captured in a model. The modeled PIP releases represent a potential range

of releases; actual releases may be lower, higher, or may not occur, and do not reflect the views of all stakeholders. These modeling assumptions are intended solely for National Environmental Policy Act analysis and do not reflect a position by Reclamation on operations that might be implemented under a PIP collaborative process.

CCS Comparative Baseline

The PIP release method under CCS Comparative Baseline is described below.

Powell Trigger

PIP releases from the UIUs (Flaming Gorge, Blue Mesa, and Navajo Reservoirs) are triggered when Lake Powell is projected to fall below an elevation of 3,525 feet. In April and August, CRSS uses a regression model to project the following March 31 Lake Powell pool elevation by estimating Powell inflows based on monthly natural flow and Upper Basin demands (see **Section A.6.2**, *Lake Powell Inflow Forecast*). Using these projected inflows and the projected Lake Powell release, CRSS determines the expected Lake Powell pool elevation. If the projection indicates that Lake Powell will drop below 3,525 feet, CRSS calculates the volume needed to reach the protection elevation of 3,525 feet (deficit volume) and initiates PIP releases to address the deficit.

Available Volume

The total volume from each UIU available for contribution to PIP releases is limited to the amount of water stored above the designated lower limit elevation. For each reservoir, a forecasting algorithm estimates the elevation for the future annual operating target month. These forecasts assume daily spring flow release patterns followed by baseflow releases under the same hydrologic conditions throughout the forecast period.

The lower limit elevation and annual operating target month for each reservoir is listed below:

- Flaming Gorge: 5,890 feet in April (May 1), which is 19 feet above minimum power pool. Typical May 1 targets range from 6,027 to 6,023 feet depending on the hydrologic conditions.
- Blue Mesa: 7,424.21 feet in December, reflecting the minimum water surface elevation (7,393 feet) plus 80 kaf of Uncompahgre Project contract water storage. In a typical year, Blue Mesa is operated to achieve a December elevation of 7,490 feet to prevent icing.
- Navajo: Minimum end of water year storage target (EOWYST) in September, which increases from 6,030 feet in 2027 to 6,052 feet in 2045. These elevations are based on minimum water surface elevation of 5,990 feet, and account for contract water storage (33.5 kaf for the Jicarilla Apache Nation and 23 kaf for the Hammond Water Conservancy District) and NIIP build-out. In years without PIP releases, CRSS forecasts whether sufficient water will be available above the EOWYST elevation of 6,050 feet to conduct a spring release. After 2043, Navajo will no longer participate in PIP releases because its minimum EOWYST will exceed the 6,050-foot threshold required for a standard spring release.

Lower limit elevations are used to determine the available volume and the annual operational targets, but rules do not protect and/or maintain lower limit storage on a month-to-month basis. UIUs can fall below lower limits, which may prevent them from meeting future environmental targets.

Releases

Maximum Annual Release
There is no maximum annual release specified.

Distribution of Releases
The total contribution to PIP releases is determined by the volume needed to reach 3,525 feet or by the total volume available in the UIUs, whichever is smaller. CRSS allocates this total contribution proportionally between Flaming Gorge and Blue Mesa based on the volume available above each reservoir's lower elevation limit. Navajo contributes during spring operations using any volume available beyond the volume used in a normal spring release. This contribution is factored into the proportional distribution between Flaming Gorge and Blue Mesa. Flaming Gorge's assigned contribution is increased if the proportional contributions do not equal the forecast deficit.

UIU Operational Adjustments
Each UIU's operations are adjusted within their Records of Decision to release an additional volume equal to the assigned contribution by modifying their operating targets. Annual contributions for each UIU are estimated at the end of each UIU's operating year.

Flaming Gorge
Flaming Gorge's May 1 target is lowered by its assigned contribution. If the reservoir did not reach its normal May 1 target in the previous year due to PIP releases, the prior May 1 elevation is adjusted by the new assigned contribution. The May 1 target elevation cannot be lower than 5,890 feet (lower limit elevation). Operations are adjusted based on the sub annual flow regime as follows:

- Spring: No changes to the Spring operations are modeled. Spring operations are modeled by a daily hydrograph which ramps up from baseflow to peak and back to baseflow. Operations vary by hydrologic classification and peak timing.
- Baseflow: The release in baseflow is the greater of the steady release to achieve the May 1 target or the minimum for Reach 2 (Jensen, Utah) for the hydrologic classification. The release in all baseflow months is constrained further by the minimum and maximum for Reach 1 (below Flaming Gorge). All maximum and minimum flows are from the 2022 Drought Response Operation Plan[2], which uses the +/- 40 percent or 25 percent flexibility in the Record of Decision and varies by season.

[2] Attachment C - Appendix 1, Estimated Normal / Maximum / Minimum Summer to Winter Baseflows in the Green River downstream from Flaming Gorge Dam, page 84-85.

Transition: Releases during the transition period in March and April are constrained to a maximum of 2,000 cubic feet per second (cfs), which is based on an operator estimate of United States (U.S.) Fish and Wildlife Service Recovery Program preference[3].

Blue Mesa

Monthly releases from Blue Mesa are the greater of three criteria: the flow required to meet the Whitewater Target for the current hydrologic classification under the Record of Decision, the Federal Reserve Water Right in the Black Canyon of the Gunnison National Park, and the flow needed to meet the guide curve storage target. Blue Mesa operations are adjusted by lowering the monthly guide curve by the assigned contribution; therefore, PIP releases only occur when the modified guide curve becomes the controlling factor. If PIP releases occurred in the prior year, the starting elevation is adjusted downward. The guide curve reduction increases gradually each month until December, when the full assigned volume is reached. The monthly guide curve storage target cannot drop below 7,424.21 feet. Releases from August through April are further limited by the Crystal Powerplant capacity.

Navajo

Navajo's PIP releases occur only during the spring release period and are based on the volume available above the EOWYST of 6,050 feet after meeting baseflow requirements. Increased releases outside of spring do not help achieve Record of Decision operational targets. Navajo's total assigned contribution is the volume above its lower limit EOWYST minus the volume used in normal spring operations. Navajo will only participate in UIU contributions in April, not August and must recover before contributing again, which occurs once it is at or above 6,063 feet at the end of the water year or conducts a spring peak release lasting at least 21 days.

Recovery

Recovery of the UIUs is not explicitly modeled. Instead, the reservoirs naturally recover in years without PIP releases as they return to their normal annual operating targets.

No Action Alternative

There are no PIP releases modeled in the No Action Alternative.

Basic Coordination Alternative

The PIP release method under the Basic Coordination Alternative is identical to that of CCS Comparative Baseline.

Enhanced Coordination Alternative

There are no PIP releases modeled in the Enhanced Coordination Alternative.

Maximum Operational Flexibility Alternative

There are no PIP releases modeled in the Maximum Operational Flexibility Alternative.

[3] Typically, the transition period is the unconstrained release to achieve the May 1 target.

Supply Driven Alternative

The PIP release method under the Supply Driven Alternative is the same as that of CCS Comparative Baseline except as noted in the following sections.

Powell Trigger

PIP releases are triggered when Lake Powell falls below elevation 3,525 feet in any month. If Lake Powell is below the protection elevation of 3,525 feet, CRSS calculates the volume needed to reach the protection elevation and initiates PIP releases to address the deficit.

Available Volume

The modeling assumptions for the Available Volume are the same as CCS Comparative Baseline except only Flaming Gorge is assumed to participate in PIP releases.

Releases

Maximum Annual Release

The maximum annual release from Flaming Gorge is 500 kaf.

Distribution of Releases

The total contribution to PIP releases is determined by the volume needed to reach 3,525 feet or by the total volume available in Flaming Gorge, whichever is less.

UIU Operational Adjustments

The UIU operational adjustments for Flaming Gorge are identical to assumptions in CCS Comparative Baseline.

Recovery

Flaming Gorge can naturally recover by returning to its normal annual operating targets once Lake Powell is above 3,535 feet.

Representative Preferred Alternative

The PIP release method under the Representative Preferred Alternative is identical to that of CCS Comparative Baseline.[4]

[4] During preparation of the Final EIS, Reclamation identified a discrepancy in the implementation of the PIP logic in CRSS used to support this analysis. While correcting the discrepancy results in small changes to the quantitative results, it does not affect the comparative evaluation of alternatives, the environmental impact analysis, or the conclusions presented in this Final EIS. Modeling to support the analysis in **TA 3**, Hydrologic Resources, and **TA 4,** Water Deliveries, was updated to reflect this PIP logic. All other resource categories rely on modeling that did not include PIP releases.

A.6 Lake Powell Operation

Lake Powell is the most downstream reservoir in the Upper Basin; it is impounded by Glen Canyon Dam near Page, Arizona, Glen Canyon Dam is 17 miles upstream of Lee Ferry, the delineation point between the Upper and Lower Basins.

Section A.6.1 describes modeling assumptions common to all alternatives. **Sections A.6.2** through **A.6.7** describe model assumptions for Lake Powell operating strategies for the comparative baseline and each alternative. The Lake Powell mechanism for the storage and delivery of conserved system and non-system water is summarized in **Appendix B**.

A.6.1 Assumptions Common to All Alternatives

Lake Powell operates on a water year (October through September) basis with an annual release set at the beginning of the water year with possible adjustments throughout the water year.

Disaggregation from Annual to Monthly Release

Lake Powell water year releases are disaggregated to monthly releases using the Long-Term Experimental and Management Plan (LTEMP) release patterns. The Lake Powell assumed monthly releases for CRSS are in **Table Attachment A1-1**. In CRSS, the water year release pattern that is less than or equal to the water year release is selected from **Table Attachment A1-1**. The monthly release is then calculated by multiplying the remaining water year release by the proportion of flow released in the given month relative to the remainder of the water year for the determined release pattern. The minimum monthly release is set to 6,521 cfs, which is consistent with the daily minimum LTEMP release.

Safe Operating Capacity Operations

If Lake Powell is nearing maximum capacity, Lake Powell's outflow is set to a volume needed to reach seasonal storage targets designed to maintain a safe operating capacity. For January through July, the model calculates the monthly release needed to meet the July Powell storage target (500 kaf below live capacity). Likewise, for August through December, the model calculates a monthly outflow needed to meet the December Powell storage target (2.422 maf below live capacity). The monthly constrained release (i.e., through the powerplant and river outlet works) is a maximum of 48,100 cfs.

Infrastructure Constraints at Low Elevations

The monthly releases can be constrained due to physical limitations at Glen Canyon Dam. Water can be released through the powerplant turbines until the pool elevation drops below 3,490 feet. Once Lake Powell is below 3,490 feet, releases are made through four river outlet works. The capacity of the river outlet works varies with the elevation of Lake Powell; the higher the pool elevation, the higher the potential release through the river outlet works. CRSS computes the maximum monthly release based on the Lake Powell elevation using **Table A-3** and interpolates for the capacity between elevations. The release capacity for each river outlet work is provided in the LaFond (2024) technical decision memorandum. For modeling purposes, three out of four river outlet works are assumed to be available for use at any given time; this is because of the need for periodic inspections and any associated maintenance activities. Reclamation believes this is a reasonable estimation given the historical and future operations and maintenance requirements for

the river outlet works. If a monthly release is constrained, the volume is tracked and is attempted to be released later in the water year to maintain the desired water year release, if possible.

Table A-3
CRSS Modeled River Outlet Works' Capacity by Lake Powell Elevation

Lake Powell Elevation	Capacity (1 river outlet work)		Capacity (3 river outlet works)	
feet	cfs	kaf/yr	cfs	kaf/yr
3,390	0	0	0	0
3,400	1,200	869	3,600	2,606
3,410	1,800	1,303	5,400	3,909
3,420	2,200	1,593	6,600	4,778
3,430	2,439	1,766	7,317	5,297
3,440	2,580	1,868	7,740	5,604
3,450	2,711	1,963	8,133	5,888
3,460	2,837	2,054	8,511	6,162
3,470	2,958	2,141	8,874	6,424
3,480	3,073	2,225	9,219	6,674
3,490	3,185	2,306	9,555	6,918

A.6.2 CCS Comparative Baseline

The CCS Comparative Baseline assumes that existing agreements, including the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), 2017 Minute 323, and 2019 DCP continue through the analysis period (2027-2060). In January, Lake Powell operating tiers are determined based on the previous end of calendar year (EOCY) pool elevation at Lake Powell. This is a modeling simplification, rather than using an August based projection of December 31 conditions, as specified in the 2007 Interim Guidelines. For October through December of the current water year, 2.0 maf is released consistent with 8.23 maf monthly release pattern unless Lake Powell is in Safe Operating Capacity Operations (**Section A.6.1**) or otherwise specified based on water year releases at 7.48 maf or lower (**Table Attachment A1-1**). In January, CRSS sets the Lake Powell operating tier and water year release as follows:

- If the Lake Powell EOCY pool elevation is greater than or equal to the Equalization Level (**Table A-6**), the Equalization Tier operations govern the water year releases.
- If the Lake Powell EOCY pool elevation is less than the Equalization Level and greater than or equal to 3,575 feet, the Upper Elevation Balancing Tier governs the water year releases.
- If the Lake Powell EOCY pool elevation is less than 3,575 feet and greater than or equal to 3,525 feet, the Mid-Elevation Release Tier governs the water year releases.
- If the Lake Powell EOCY pool elevation is less than 3,525 feet, the Lower Elevation Balancing Tier governs the water year releases.

Additional details on modeled operations in each of these tiers are included in the following sections.

Lake Powell Inflow Forecast

The Lake Powell inflow forecast is used to estimate future Lake Powell storage. The unregulated Lake Powell inflow forecast from the current month through the forecasted month is computed as:

$$unregulated\ Lake\ Powell\ inflow = natural\ flow\ above\ Lake\ Powell\ -\ estimated\ Upper\ Basin\ depletions + the\ forecast\ error$$

The *estimated Upper Basin depletions* (consumptive use) are computed using a logistic regression equation. The following formula operates at a monthly level, using the parameters outlined in **Table A-4**. The coefficients were estimated using modeled CRSS depletions as the predicant, and monthly input natural flow and Upper Basin demands as the predictors using data from the Colorado River Post-2026 Operations Exploration Tool[5].

$$UBDep_i = p1_i * (1.0 - \frac{1.0}{1 + e^{2.718 - p3_i * (NF_i - p2_i)}}) - p4_i * (\frac{UBDem_{Ann}}{1 + e^{2.718 - p6_i * (NF_i - p5_i)}})$$

where:

i = month,
UBDep = estimated total Upper Basin depletion (use) for month *i* in maf,
NF = total natural flow above Lees Ferry for month *i* in af,
$UBDem_{Ann}$ = total Upper Basin demand for the year in maf, and
p1, p2, p3, p4, p5, p6 = coefficients for the logistic regression equation (**Table A-4**).

Table A-4
Monthly Estimated Upper Basin Depletion Equation Coefficients

Month	p1 (af)	p2 (af)	p3 (1/af)	p4 (none)	p5 (af)	p6 (1/af)
January	0.7775	-4.5631	0.6096	0.7962	8.6430	0.5274
February	0.5652	-13.4136	0.1904	0.1406	8.5226	0.3441
March	0.0582	-2.3241	-5.5242	0.0121	-0.1326	2.8745
April	0.0900	0.2109	-6.1404	0.0347	-0.3668	1.0723
May	0.7588	0.1828	-0.8157	2.348E-09	-6.9129	-4.9230
June	1.1473	0.6672	-0.7058	2.129E-05	-7.4173	-13.9783
July	3.5042	-6.7974	4.8519	0.1977	0.5144	1.2987
August	0.2381	-5.7046	-3.7719	0.0797	0.4006	3.0123
September	0.1087	-2.2124	-5.8441	0.0539	-0.0214	2.7065
October	0.0478	-1.6741	-7.1793	0.0277	-0.1222	3.2833
November	1.3998	-4.0494	0.9816	0.0149	-0.0457	1.7068
December	1.0081	-1.2688	2.2497	0.0182	0.2702	2.9061

[5] www.crbpost2026dmdu.org

The *forecast error* is computed using equations derived from an analysis of past Colorado River forecasts and runoff data for the period 1947 to 1983. An analysis of these data reveals two strongly established patterns: (1) high runoff years are under-forecast, and low runoff years are over-forecast; and (2) the error in the current month's seasonal forecast is strongly correlated with the error in the preceding month's forecast (Reclamation 1985). A regression model was developed to aid in determining the error to be incorporated into the seasonal forecast for each month from January to June. The error in months after June is assumed to be negligible compared to the error during the runoff season. The error is the sum of a deterministic component and a random component. The deterministic component is computed from the regression equation. The random component is computed by multiplying the standard error of the regression equation by a random mean deviation selected from a standard normal distribution. The forecast error equation has the following form (all runoff units are maf):

$$E_i = a_i X_i + b_i E_{(i-1)} + c_i + Z_r d_i$$

where:

i = month,
E_i = error in the forecast for month i,
X_i = natural runoff into Lake Powell from month i through July,
a_i = linear regression coefficient for X_i,
$E_{(i-1)}$ = previous month's forecast error,
b_i = linear regression coefficient for $E_{(i-1)}$,
c_i = constant term in regression equation for month i,
Z_r = randomly determined deviation, and
d_i = standard error of estimate for regression equation for month i.

Table A-5 summarizes the regression equation coefficients for each month.

Table A-5
Lake Powell Inflow Forecast Regression Equation Coefficients

Month	a_i	b_i	c_i	d_i
January	0.70	0.00	-8.195	1.270
February	0.00	0.80	-0.278	0.977
March	0.00	0.90	0.237	0.794
April	0.00	0.76	0.027	0.631
May	0.00	0.85	0.132	0.377
June	0.24	0.79	0.150	0.460

The magnitude of the June forecast error is constrained to not exceed 50 percent of the May forecast error and the July forecast error is equal to 25 percent of the June forecast error.

Predicting End of Water Year Volumes of Lake Powell and Lake Mead

Lake Powell end of water year (EOWY) volume is predicted each month by taking the end of the previous month's storage, adding the forecasted inflow as described in the previous section, subtracting the estimated release, and subtracting the estimate of evaporation and change in bank

storage. All estimated values are for the period from the current month through September. The estimated release is based on the operation of the alternative. The estimated evaporation and bank storage losses are based on an initial estimate of the EOWY volume.

Similarly, the Lake Mead EOWY volume is predicted each month by taking the end of the previous month's volume, adding the estimated Lake Powell release, subtracting the estimated Lake Mead release, adding the average gain between Lake Powell and Lake Mead, subtracting the Southern Nevada depletion, and subtracting the estimate of evaporation and change in bank storage. Again, all values are for the period from the current month through September. Lake Mead's release is estimated as the sum of the depletions downstream of Lake Mead and the reservoir regulation requirements (including evaporation losses) for Lake Mohave and Lake Havasu minus/plus the gains/losses below Lake Mead.

Equalization Tier

Under CCS Comparative Baseline, the equalization of storage between Lake Powell and Lake Mead is modeled with a rule that first determines if equalization needs to occur, and if so, then the rule determines how much water would be released to equalize Lakes Powell and Mead. The rule is in effect from January through September of each year. The rule states that equalization occurs if two criteria are met: (1) if the previous end-of-year Lake Powell elevation is greater than or equal to the Equalization Level (see **Table A-6**); and (2) if the projected EOWY storage in Lake Powell is greater than or equal to the projected EOWY storage in Lake Mead (the previous section describes EOWY projections). For modeling purposes, the Equalization Level used in CCS Comparative Baseline extends the 2007 Interim Guidelines Equalization Level through 2060, using the same calculation and parameters that were used to develop the 2007 Interim Guidelines Equalization Level. **Appendix J** describes the 602(a) storage calculation, which forms the basis for the Equalization Level under the 2007 Interim Guidelines. It documents the parameters used in the 2007 calculation, which are also used in this extension through 2060. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.

If operating in the Equalization Tier, the water year release is computed as the release required to balance the contents of Lake Powell and Lake Mead by the end of the water year and constrained such that the release does not cause Lake Powell to decline below the Equalization Level unless Lake Mead is less than 1,105 feet. If Lake Mead is projected to decline below 1,105 feet, then Lake Powell's release is increased until the first of the following three conditions occurs: 1) the reservoirs storage is equal, 2) Lake Mead EOWY storage is 1,105 feet, or 3) Lake Powell EOWY elevation is 20 feet below the Equalization Level Line. The monthly release from Lake Powell is then calculated using the method as described under **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Upper Elevation Balancing Tier

Operations in the Upper Elevation Balancing Tier differ depending on the month. In January through March, if the Lake Mead EOCY pool elevation is less than 1,075 feet, the water year release necessary to balance Lake Powell and Lake Mead projected EOWY storage (as calculated in **Section A.6.2**, *Predicting End of Water Year Volumes of Lake Powell and Lake Mead*) is calculated but constrained to be within the range of 7.0 to 9.0 maf. If the Lake Mead EOCY pool elevation is greater than or equal to 1,075 feet, then set the water year release to 8.23 maf.

Table A-6
Lake Powell Equalization Level Table

Year	Equalization Elevation (feet)	Year	Equalization Elevation (feet)
2027	3,667	2044	3,688
2028	3,668	2045	3,689
2029	3,670	2046	3,690
2030	3,671	2047	3,691
2031	3,672	2048	3,692
2032	3,673	2049	3,693
2033	3,674	2050	3,694
2034	3,675	2051	3,695
2035	3,677	2052	3,695
2036	3,678	2053	3,696
2037	3,679	2054	3,696
2038	3,680	2055	3,697
2039	3,682	2056	3,697
2040	3,683	2057	3,697
2041	3,684	2058	3,698
2042	3,686	2059	3,698
2043	3,687	2060	3,698

In April, Lake Powell can switch to equalization operations if the projected Lake Powell EOWY pool elevation is above the Equalization Level and the projected Lake Powell EOWY storage is greater than the projected Lake Mead EOWY storage. If operating in equalization, the water year release is set based on equalization logic (described in the previous section) and constrained to a minimum of 8.23 maf.

Otherwise, if Lake Powell's projected EOWY pool elevation is less than or equal to the Equalization Level, Lake Powell's releases are modeled as follows:

- If the year started by balancing contents between Lake Powell and Lake Mead constrained between 7.0 and 9.0 maf, continue these operations for the remainder of the water year
- If the April projected Lake Mead EOWY pool elevation is less than 1,075 feet and the April projected Lake Powell EOWY pool elevation is greater than 3,575 feet, then compute the water year release necessary to balance Lake Powell and Lake Mead projected EOWY storage, constrained between 8.23 maf and 9.0 maf.
- Otherwise (the April projected Lake Mead EOWY pool elevation is greater than 1,075 feet or the April projected Lake Powell EOWY pool elevation is less than 3,575 feet), continue with a water year release of 8.23 maf.

The monthly release from Lake Powell is then calculated using the method as described under **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Mid-Elevation Release Tier

At the beginning of the water year, if Lake Powell elevation is less than 3,575 feet and greater than or equal to 3,525 feet, and Mead is greater than or equal to 1,025 feet, Lake Powell will release 1.58 maf over the months of October through December, as opposed to a 2.0 maf release. At the beginning of the calendar year, the Lake Powell operating tier is set. If the operating tier is the Mid-Elevation Release Tier, CRSS will check the Lake Mead EOCY pool elevation. If the Lake Mead EOCY pool elevation is greater than or equal to 1,025 feet, Lake Powell's water year release is set to 7.48 maf. Otherwise, the water year release is set to 8.23 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Lower Elevation Balancing Tier

The Lower Elevation Balancing Tier (Lake Powell elevation less than 3,525 feet) is modeled by calculating the release necessary to balance Lake Powell and Lake Mead's projected EOWY storage (as calculated in **Section A.6.2**, *Predicting End of Water Year Volumes of Lake Powell and Lake Mead*) but constrained to be within the range of 7.0 to 9.5 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Reduced Releases in the Mid-Elevation Release and Lower Elevation Balancing Tiers

The 2024 Near-term Colorado River Operations Final Supplemental EIS (Reclamation 2024) states:

> When operating in the Mid-Elevation Release Tier or the Lower Elevation Balancing Tier, Reclamation will consider all tools that are available during the interim period to avoid Lake Powell elevation declining below 3,500 feet. If the minimum probable 24-Month Study projects in any month an elevation below 3,500 feet in the next 12 months, the Secretary shall begin planning to reduce releases, as needed, to not less than 6.0 maf from Lake Powell in the Water Year to maintain an elevation of 3,500 feet[6].

In CRSS, this is modeled by assuming Lake Powell operations can be adjusted to protect 3,500 feet in any month when Lake Powell is operating in the Mid-Elevation Release Tier or Lower Elevation Balancing Tier. CRSS first checks the current month's Lake Powell pool elevation and the projected EOWY Lake Powell pool elevation with an assumed 6 maf release to determine the monthly release.

- If the projected EOWY Lake Powell pool elevation with a 6 maf is less than 3,500 feet, the water year release is set to 6.0 maf and the monthly release is calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*
- If the current Lake Powell pool elevation is below 3,500 feet but the projected EOWY Lake Powell pool elevation is greater than 3,500 feet, the current month's release is decreased such that the Lake Powell pool elevation is maintained at or above 3,500 feet; however, it is

[6] The Secretary reserves the right to operate Reclamation facilities to protect the Colorado River system if hydrologic conditions require such action as described in Sections 6 and 7(D) in the 2007 Interim Guidelines ROD.

subject to the following constraints: the minimum water year release is 6.0 maf, and the monthly release will be no less than the volume necessary to meet the minimum daily LTEMP release (6,521 cfs).

If releases are adjusted to protect 3,500 feet during a given month of the water year and Lake Powell pool elevation increases above 3,500 feet, monthly releases can be increased to release up to the original water year release for the given Lake Powell operating tier.

A.6.3 No Action Alternative

In the No Action Alternative, Lake Powell annual operations are assumed to be based on the EOCY pool elevation at Lake Powell (**Figure A-1**). For October through December, 2.0 maf is released consistent with 8.23 maf monthly release pattern (**Table Attachment A1-1**) unless Lake Powell is in Safe Operating Capacity Operations (**Section A.6.1**, *Safe Operating Capacity Operations*). In January, CRSS sets the Lake Powell operations using the EOCY pool elevation:

- If the Lake Powell EOCY pool elevation is greater than or equal to the Equalization Level (**Table A-6**), the equalization operations govern the water year releases. For modeling purposes, the Equalization Level used in the No Action Alternative extends the 2007 Interim Guidelines Equalization Level through 2060, using the same calculation and parameters that were used to develop the 2007 Interim Guidelines Equalization Level. **Appendix J** describes the 602(a) storage calculation, which forms the basis for the Equalization Level under the 2007 Interim Guidelines. It documents the parameters used in the 2007 calculation, which are also used in this extension through 2060. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.
- If the Lake Powell EOCY pool elevation is less than the Equalization Level, the water year release is set to 8.23 maf.

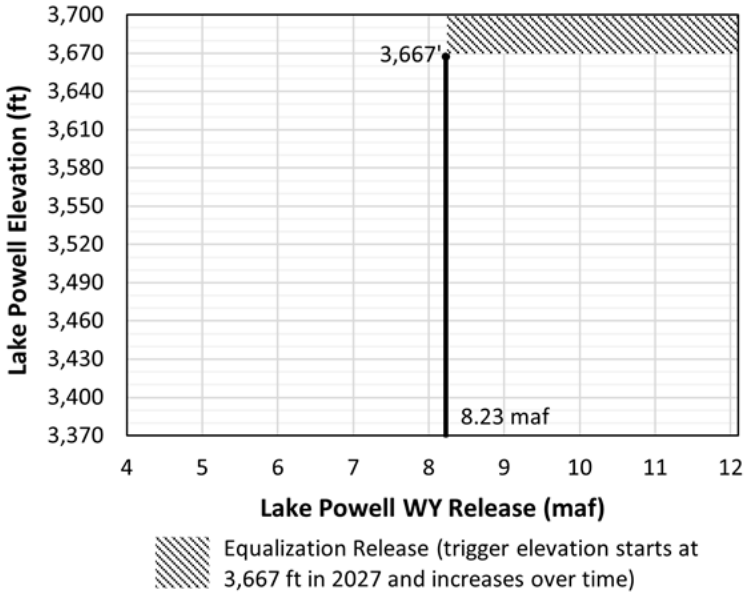
Coordination at High Elevations

Under the No Action Alternative, equalization releases are made from January to September. The water year release is computed as the release required to balance the contents of Lake Powell and Lake Mead by the end of the water year with a minimum release of 8.23 maf and constrained such that the release does not cause Lake Powell to decline below the Equalization Level (**Table A-6**). The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Primary Operations

Minimum objective release operations set the water year release to 8.23 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Figure A-1
Lake Powell Operations, No Action Alternative



A.6.4 Basic Coordination Alternative

The Lake Powell water year release is determined in October based on the previous EOWY Lake Powell storage/pool elevation (September 30).

- If the Lake Powell previous EOWY storage is greater than or equal to the 602(a) storage volume and Lake Powell EOWY storage is greater than Lake Mead EOWY storage, the equalization operations govern the water year releases.
- If the Lake Powell previous EOWY storage is less than the 602(a) storage volume or Lake Powell EOWY storage is less than Lake Mead EOWY storage, the water year release is set based on the EOWY pool elevation as shown in **Figure A-2**.

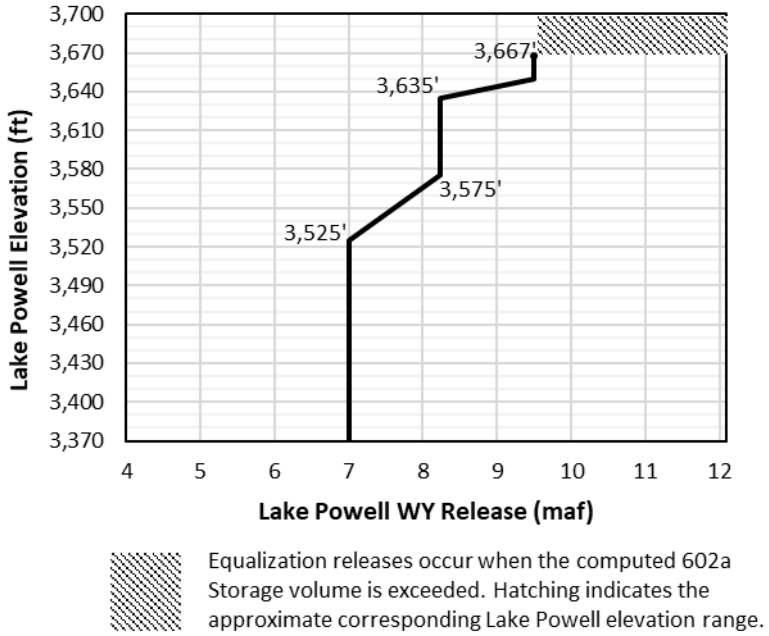
Coordination at High Elevations

If the combined Colorado River Storage Project (CRSP) storage is above the 602(a) storage volume at the previous EOWY and Lake Powell EOWY storage is greater than Lake Mead EOWY storage, equalization operations determine the water year release. A detailed description of the 602(a) storage volume calculation and parameters used in the calculation is found in **Appendix J**. For modeling purposes, the same parameters that were used to compute the 602(a) storage volume for the 2007 Interim Guidelines Equalization line are used for the Basic Coordination Alternative. In this alternative, the 602(a) storage volume is not converted to a Powell elevation. The water year release is set to the minimum of the volume needed to bring the CRSP storage down to the calculated 602(a) storage volume[7] or to balance the Lake Powell and Lake Mead projected EOWY storage, but no lower than 9.5 maf (the maximum release in primary operations). The modeled 602(a) storage

[7] The modeled logic erroneously referenced the CCS Comparative Baseline and No Action Alternative Equalization Level, rather than the intended 602(a) storage volume.

volume grows over time; in 2027, the volume is 25,082,344 af, and in 2060 it reaches 29,647,144 af. Equalization may only be triggered at the start of the water year, and once an equalization determination is made, Lake Powell operates in the Equalization Tier for the remainder of the water year. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.

Figure A-2
Lake Powell Operations Diagram, Basic Coordination Alternative



Primary Operations

The water year release when Lake Powell is not in equalization is calculated as follows:

- If the previous EOWY Lake Powell elevation is above elevation 3,650 feet and an equalization determination has not been made, the water year release is 9.5 maf.
- If the previous EOWY Lake Powell elevation is between 3,635 feet and 3,650 feet, the water year release volume linearly increases from 8.23 maf at elevation 3,635 feet to 9.5 maf at elevation 3,650 feet.
- If the previous EOWY Lake Powell elevation is between 3,575 feet and 3,635 feet, the water year release is 8.23 maf.
- If the previous EOWY Lake Powell elevation is between 3,525 feet and 3,575 feet, the water year release volume linearly increases from 7.0 maf at elevation 3,525 feet to 8.23 maf at elevation 3,575 feet.
- If the previous EOWY Lake Powell elevation is below 3,525 feet, the water year release is 7.0 maf.

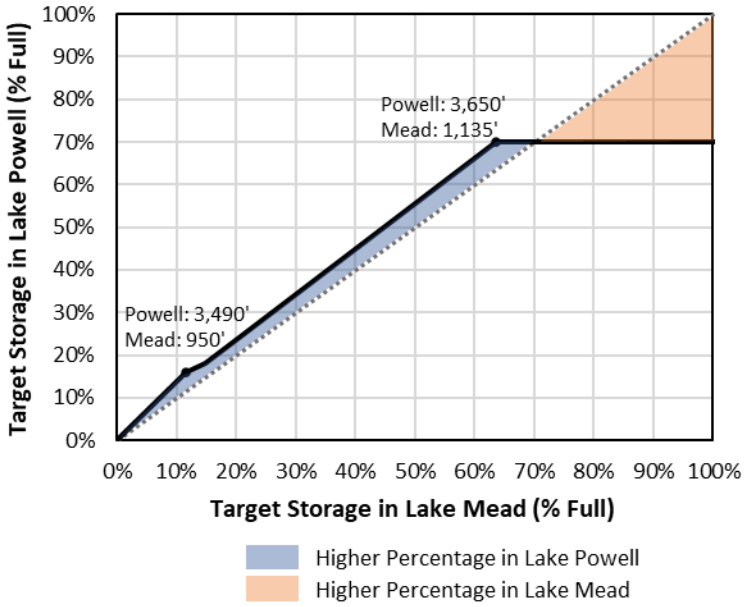
The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

A.6.5 Enhanced Coordination Alternative

Lake Powell operations target a specific distribution of storage across Lake Powell and Lake Mead for any given total volume of water as shown in **Figure A-3**. The dotted diagonal line marks a 50/50 split for reference, and the target storage curve is variable across that line, indicating the portion where Lake Powell is at higher percent capacity than Lake Mead (emphasized with blue shading) and the portion where Lake Mead is at higher percent capacity than Lake Powell (emphasized with orange shading).

- From 0 percent to 63 percent combined storage, operations would target keeping more water in Lake Powell.
- Above 63 percent full, a greater portion of water would be proactively sent to Lake Mead to prevent unplanned spill-avoidance releases and protect Glen Canyon Dam at high elevations.

Figure A-3
Coordinated Operations of Lake Powell and Lake Mead, Enhanced Coordination Alternative



The targets for coordinated operations can also be represented in a tabular format as shown in **Table A-7**.

Table A-7
Target Storages for Coordination Operations of Lake Powell and Lake Mead, Enhanced Coordination Alternative

Mead Storage (af)	Powell Storage (af)	Combined Storage (af)
0	0	0
2,005,585	3,742,714	5,748,299
3,156,353	4,215,805	7,372,158
4,475,301	5,544,923	10,020,224
15,107,119	16,309,410	31,416,529
23,143,714	16,321,726	39,465,440

Primary Operations

In October, an initial water year release is determined; in April, a one-time mid-year adjustment can be made to the water year release. The Lake Powell initial water year release is calculated based on the following factors:

- Previous EOWY physical storage of Lake Powell and Lake Mead (V_{EOWY}^{Powell}, V_{EOWY}^{Mead}, respectively)
- Target storage distribution (from **Figure A-3**)
- Preceding 10-year running average inflow to Lake Powell ($\bar{I}_{10}$)
- Lower Basin shortage for upcoming calendar year (S; see **Section A.7.5**)

CRSS first calculates the EOWY Lake Powell Target Storage (V_{target}^{Powell}) by linearly interpolating values in **Table A-7** based on the combined previous EOWY storage of Lake Powell and Lake Mead (i.e., $V_{EOWY}^{Powell} + V_{EOWY}^{Mead}$). The initial water year release (R) is then calculated as:

$$R = (V_{EOWY}^{Powell} - V_{target}^{Powell}) + I_{10} - S$$

The water year release volume must be greater than or equal to 4.72 maf, which is LTEMP daily minimum release converted to a water year volume, and less than or equal to 10.8 maf, which is the water year volume consistent with the monthly flow of 900 kaf to prevent large release volumes causing sand evacuation below Glen Canyon Dam. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

In April, a mid-year adjustment to the water year release can be made if the Lake Powell projected storage is too far off target. A new V_{target}^{Powell} is calculated using the method summarized above, but the forecasted EOWY combined Lake Powell and Lake Mead storage (i.e., $V_{EOWY}^{Powell} + V_{EOWY}^{Mead}$) is used instead of the previous year's values. The adjustment volume is then calculated as the difference between the forecasted EOWY Lake Powell storage and V_{target}^{Powell}.

There is no adjustment to the water year release if any of the following conditions are met:

- The absolute value of adjustment volume is less than 1.0 maf.
- If the projected EOWY or end-of-March Lake Powell storage is less than or equal to 3,525 feet and the release adjustment is greater than zero.
- If the projected EOWY or end-of-March Lake Powell storage is greater than 3,650 feet and the release adjustment is less than zero.

An adjusted water year volume is determined by adding the adjustment volume to the initial water year release, and is still subject to the minimum and maximum water year release volumes of 4.72 and 10.8 maf, respectively.

A.6.6 Maximum Operational Flexibility Alternative

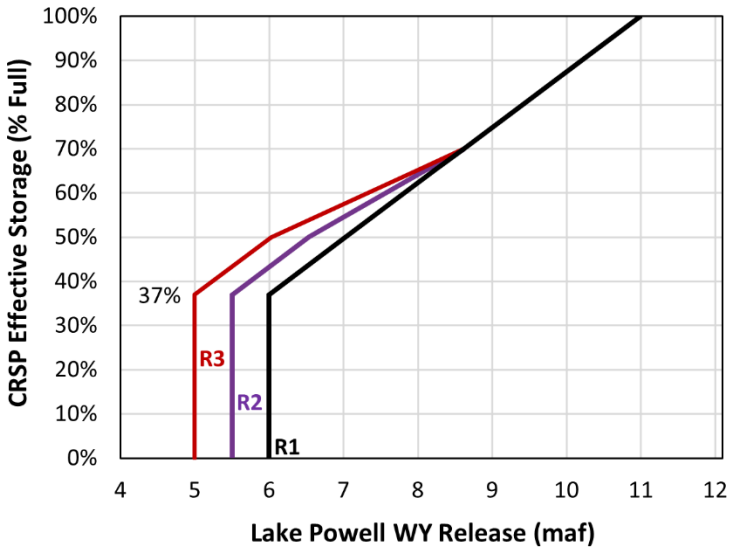
The Lake Powell water year release is set in October using the previous EOWY effective[8] storage of CRSP reservoirs (Lake Powell, Flaming Gorge, Blue Mesa, and Navajo) and a climate response indicator[9], as described below. The Conservation Reserve, which is a storage mechanism for conserved water in Lake Powell and/or Lake Mead, is assumed to be subtracted from the physical storage so that it does not affect Lake Powell operations. The Conservation Reserve modeling assumptions are described in **Appendix B**.

Lake Powell operations are shown in **Figure A-4** and are determined based on the following release regimes:

- If the CRSP effective storage is less than or equal to 100 percent and greater than 37 percent, releases range from 11 maf to 6 maf.
- If the CRSP effective storage is less than 37 percent, the water year release is set to 6 maf unless run-of-river operations are triggered.
- Releases can be adjusted by up to one maf, depending on the previous 3-year average Lees Ferry natural flow, as described in the following section.

[8] "Effective" elevation or storage is calculated as physical elevation (storage) minus any conserved volume that is held in the respective reservoir(s).
[9] For modeling purposes, the previous 3-year average Lees Ferry natural flow is used.

Figure A-4
Lake Powell Operations Diagram, Maximum Operational Flexibility Alternative



Primary Operations

The Lake Powell water year release is based on CRSP effective storage and the previous 3-year average natural flow at Lees Ferry, Arizona. Base water year releases are decreased by up to 1.0 maf consistent with **Table A-8**, and are summarized below. Natural flow and consumptive use data for a given year become available mid-following year, so a one-year lag is applied to align inputs with operational availability. For example, 2027 operations would be informed by the 2023-2025 average natural flow.

- When the CRSP effective storage is at or below 100 percent of capacity and at or above 70 percent of capacity, a release volume would be determined for that year based on a function of storage, with 11.0 maf release at 100 percent of capacity decreasing linearly to 8.6 maf at 70 percent of capacity.
- When the CRSP effective storage is at or below 70 percent of capacity and at or above 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 7.0 maf at 50 percent of capacity (R1 curve in **Figure A-4**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.5 maf at 50 percent of capacity (R2 curve in **Figure A-4**).
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a

release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.0 maf at 50 percent of capacity (R3 curve in **Figure A-4**).

- When the CRSP effective storage is at or below 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 7 maf at 50 percent of capacity decreasing linearly to 6.0 maf at 37 percent of capacity (R1 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 6.0 maf.
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.5 maf at 50 percent of capacity decreasing linearly to 5.5 maf at 37 percent of capacity (R2 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 5.5 maf.
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.0 maf at 50 percent of capacity decreasing linearly to 5.0 maf at 37 percent of capacity (R3 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 5.0 maf.

Table A-8
Release Curves and Relevant Conditions, Cooperative Conservation Alternative

Lake Powell Release Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Release Decrease Compared to R1 Curve at 50% Full (kaf)
R1	≥ 10	N/A
R2	< 10 to ≥ 8	500
R3	< 8	1,000

The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

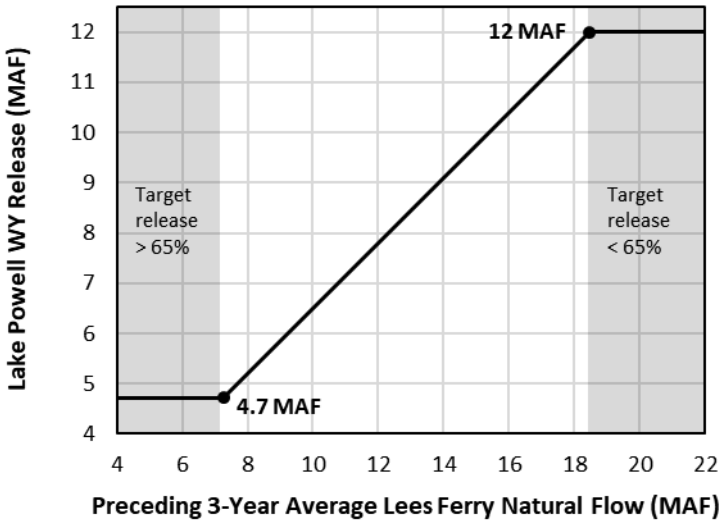
Run-of-River Operations

In any month, if the Lake Powell elevation is projected to be below 3,510 feet under primary operations, Lake Powell will operate in run-of-river operations to protect infrastructure. Lake Powell monthly releases would be calculated as the minimum of Powell's inflow minus gains and losses and the calculated release to achieve the water year release determined in the previous section. The minimum monthly release is assumed to be 5,000 cfs.

A.6.7 Supply Driven Alternative

The Lake Powell water year release is calculated in October based on the preceding 3-year natural flow and is depicted in **Figure A-5**.

Figure A-5
Lake Powell Operations Diagram, Supply Driven Alternative



Primary Operations

The Lake Powell water year release is calculated using the following equation:

$$Release = NF\% \; x \; 3 \; Year \; Avg \; NF$$

where:

NF% = 65%

3-Year Avg NF = 3-year preceding average natural flow is available at a one-year lag to align with the operational availability of natural flow and consumptive use data, which is available mid-following year for a given year. For example, 2027 operations would be informed by the 2023-2025 average natural flow.

Appendix D explores the implications of using different natural flow percentages.

The release is constrained to between 4.72 maf and 12.00 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release.*

Gap Water

In years when Lake Powell cannot meet its required water year release because of low elevation infrastructure constraints, additional water is introduced into the system to (partially) make up the shortfall. For modeling purposes, this supplemental volume is termed "gap water." In CRSS, this volume is computed monthly, when the monthly release is reduced based on the low elevation infrastructure constraints (**Section A.6.1**, *Infrastructure Constraints at Low Elevations*). If this occurs, gap

water is injected above Lake Powell with limits on the annual volume based on the following calculation:

$$G_i = max\left(min\left(O_{i,u} - O_{i,c}\,,\, G_{max} - \sum_{n=j}^{i} G_n\right), 0\ af\right)$$

where:

i = month
G = gap water injected in a given month
$O_{i,u}$ = monthly release volume before constrained by infrastructure
$O_{i,c}$ = monthly release volume after constrained by infrastructure
j = October

The maximum water year gap water volume is assumed to be:

$$G_{max} = 23\% * Annual\ WY\ Estimated\ UB\ Depletion - UB\ Conservation$$

where:

23% = Lower Basin maximum shortage in this alternative divided by the total Lower Basin apportionment to the U.S. and Mexico (2.1/9 maf)

Annual WY Estimated UB Depletion = sum of the current year's projected Upper Basin depletion (estimated using the logistic regression described in **Section A.6.2**, *Lake Powell Inflow Forecast*) and the previous year's Upper Basin CRSS reservoir evaporation.

UB Conservation = water year Upper Basin conservation defined in **Appendix B**.

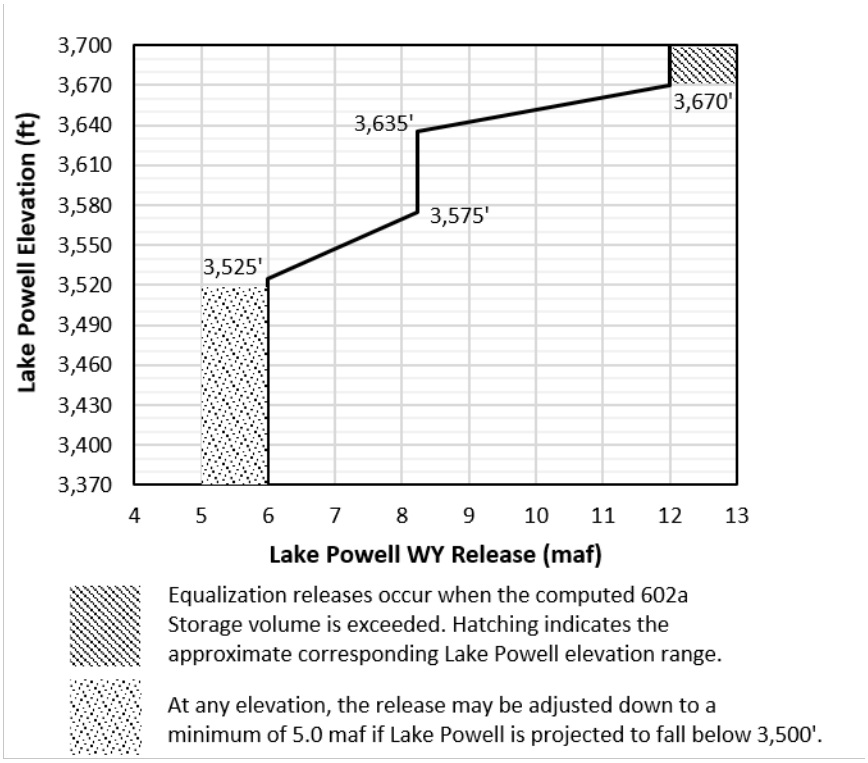
If the water year release volume cannot be released due to infrastructure constraints, the volume not released is tracked as 'Carryover'. The maximum carryover is constrained by the annual gap water volume. The model will try to release the Carryover volume in the following year(s) within the maximum release constraint of 12 maf.

A.6.8 Representative Preferred Alternative

The Lake Powell water year release is determined in October based on the previous EOWY Lake Powell storage/pool elevation (September 30).

- If the Lake Powell previous EOWY storage is greater than or equal to the 602(a) storage volume and Lake Powell EOWY storage is greater than Lake Mead EOWY storage, the equalization operations govern the water year releases.
- If the Lake Powell previous EOWY storage is less than the 602(a) storage volume or Lake Powell EOWY storage is less than Lake Mead EOWY storage, the water year release is set based on the EOWY pool elevation as shown in **Figure A-6**.

Figure A-6
Lake Powell Operations Diagram, Representative Preferred Alternative



Coordination at High Elevations

The Representative Preferred Alternative assumes equalization operations occur at high elevations in Lake Powell. The equalization operations modeled in the Representative Preferred Alternative are identical to the Basic Coordination Alternative (**Section A.6.4**, *Coordination at High Elevations*) except the minimum equalization release during equalization is assumed to be equal to the maximum release in the primary operation based on Lake Powell's EOWY elevation, which is typically 12 maf.

Primary Operations

The water year release when Lake Powell is not in equalization is calculated as follows:

- If the previous EOWY Lake Powell elevation is above elevation 3,670 feet and an equalization determination has not been made, the water year release is 12.0 maf.
- If the previous EOWY Lake Powell elevation is between 3,635 feet and 3,670 feet, the water year release volume linearly increases from 8.23 maf at elevation 3,635 feet to 12.0 maf at elevation 3,670 feet.
- If the previous EOWY Lake Powell elevation is between 3,575 feet and 3,635 feet, the water year release is 8.23 maf.
- If the previous EOWY Lake Powell elevation is between 3,525 feet and 3,575 feet, the water year release volume linearly increases from 6.0 maf at elevation 3,525 feet to 8.23 maf at elevation 3,575 feet.

- If the previous EOWY Lake Powell elevation is below 3,525 feet, the water year release is 6.0 maf.

The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Reduced Releases for Infrastructure Protection

Lake Powell releases can be reduced to a minimum of 5.0 maf if Lake Powell is projected to drop below 3,500 feet during the water year. In the model, CRSS first checks the current month's Lake Powell pool elevation and the projected EOWY Lake Powell pool elevation with an assumed 5.0 maf release to determine the monthly release.

- If the projected EOWY Lake Powell pool elevation with a 5.0 maf is less than 3,500 feet, the water year release is set to 5.0 maf and the monthly release is calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.
- If the current Lake Powell pool elevation is below 3,500 feet but the projected EOWY Lake Powell pool elevation is greater than 3,500 feet, the current month's release is decreased such that the Lake Powell pool elevation is maintained at or above 3,500 feet; however, it is subject to the following constraints: the minimum water year release is 5.0 maf, and the monthly release will be no less than the volume necessary to meet the minimum daily LTEMP release (6,521 cfs).

If releases are adjusted to protect 3,500 feet during a given month of the water year and Lake Powell pool elevation increases above 3,500 feet, monthly releases can be increased to release up to the original water year release.

A.7 Lake Mead Operation

Lake Mead is the uppermost reservoir in the Lower Basin. Located 35 miles southeast of Las Vegas, the 726-foot-high Hoover Dam impounds Lake Mead. In CRSS, Lake Mead operations are modeled by solving for the Lower Basin condition, Lower Basin and Mexico diversions, including the conservation, storage, and delivery of conserved system and non-system water, and then setting Lake Mead's outflow to meet all downstream diversions.

Section A.7.1 describes the CRSS modeling assumptions common to all alternatives. **Sections A.7.2** through **A.7.7** describe assumptions for Lake Mead operating strategies for each alternative. The assumptions for the Lake Mead mechanism for storage and delivery of conserved system and non-system water are summarized in **Appendix B**.

A.7.1 Assumptions Common to All Alternatives

CRSS solves for the Lower Basin operating condition for the calendar year in January using a specified system condition that varies between alternatives. Each month, the rule computes downstream depletions based on scheduled inputs that are adjusted as necessary for shortage, surplus, conservation storage, and conservation delivery, as well as the volume of water needed to

meet storage targets at Lake Mohave and Lake Havasu and to offset evaporation losses at those lakes. The rule then determines the total monthly release required from Lake Mead to satisfy downstream demand, taking into account gains and losses below Lake Mead.

Water User Depletions

The depletions from Lake Mead and downstream of Hoover Dam are affected by the determination of the water supply conditions (Normal, Surplus, or Shortage) as described below in each alternative's section. Individual water users' monthly depletions are adjusted using the following equation:

$$Depletion = Schedule - Shortage + Surplus - Conservation\ Creation + Conservation\ Delivery$$

Annual volumes of shortage, surplus, and conservation activities are disaggregated to monthly volumes proportionally to a user's monthly and annual scheduled water use:

$$MonthlyVolume = AnnualVolume * \left(\frac{Monthly\ WaterUseSchedule}{AnnualWaterUseSchedule}\right)$$

Water to Mexico in Excess of Treaty Requirements and Water Bypassed Pursuant to International Boundary and Water Commission Minute 242

In CRSS, Lake Mead may release additional water to account for two types of flows to Mexico beyond the treaty-scheduled deliveries: (1) water passing to Mexico in excess of monthly schedules which reflects the treaty requirements and (2) water bypassed pursuant to International Boundary and Water Commission (IBWC) Minute 242.

Assumed annual volumes for these purposes are derived from historical data, relying on the Lower Colorado Basin Decree Accounting Reports when available, or from Reclamation's provisional estimates. The assumed annual volume for water passing to Mexico in excess of treaty requirements is based on a 5-year average updated as data become available. For this EIS, the most recent 5-year average relied on data from 2019-2023; however, 2023 was excluded because it was a flood year on the Gila River, so the value is based on 2019-2022 and was computed to be 32,413 af[10]. The assumed annual volume for water bypassed pursuant to IBWC Minute 242 is based on the long-term average from 1990-2023 and was computed to be 118,474 af[11].

For both water passing to Mexico in excess of treaty requirements and water bypassed pursuant to IBWC Minute 242, the annual averages are used for all years of the model simulation and are disaggregated to monthly volumes using monthly distribution coefficients in **Table A-9**.

[10] 2019-2021 data were obtained from the published Decree Accounting Reports and a provisional value for 2022 of 8,982 af was used, although final 2022 data were available at the time of the calculation.
[11] 1990-2021 data were obtained from the published Decree Accounting Reports. Provisional values of 141,047 and 116,738 af were used for 2022 and 2023, respectively. Although final 2022 data were available at the time of the calculation, the provisional value was used.

Table A-9
Monthly Distribution Coefficients (percent) and Annual Volume (af) of the Water Passing to Mexico in Excess of Treaty Requirements and Water Bypassed Pursuant to IBWC Minute 242

Month Distribution Coefficients	Water Passing to Mexico in Excess of Treaty Requirements	Water Bypassed Pursuant to IBWC Minute 242
Jan	5.3%	8.6%
Feb	6.3%	8.3%
Mar	20.4%	8.9%
Apr	12.5%	8.6%
May	4.0%	8.6%
Jun	0.9%	8.0%
Jul	1.2%	7.7%
Aug	2.1%	7.4%
Sep	11.5%	8.0%
Oct	8.3%	9.2%
Nov	17.8%	8.5%
Dec	9.7%	8.3%
Annual Volume	32,423 af	118,474 af

Lake Mead/Hoover Dam Flood Control

Under certain conditions, Lake Mead may release water in addition to downstream demand. This condition is termed "flood control" and is guided by the U.S. Army Corps of Engineers' (USACE's) flood control regulations as contained in the USACE's Water Control Manual for Flood Control, Hoover Dam and Lake Mead, Colorado River, Nevada and Arizona (Water Control Manual) dated December 1982.

In CRSS, there are three flood control procedures currently in effect for different times of the year. These procedures were developed in the original CRSS and are based on the Field Working Agreement between Reclamation and the USACE (USACE 1982). The first procedure is in effect throughout the year. Its objective is to maintain a minimum space of 1.5 maf in Lake Mead, primarily for extreme rain events. This space is referred to as the exclusive flood control space and is represented by the space above elevation 1,219.64 feet. The second procedure is used during the period from January through July. The objective during this period is to route the maximum inflow forecast through the reservoir system using specific rates of Hoover Dam discharge, assuming that Lake Mead will fill to elevation 1,219.64 feet at the end of July. The third procedure is used during the space building or drawdown period (August through December). The objective during this period is to gradually draw down the reservoir system to meet the total system space requirements in each month in anticipation of the next year's runoff.

Exclusive Flood Control Space Requirement

This requirement states that there must be a minimum space of 1.5 maf in Lake Mead at all times. If the release computed to meet downstream demand results in a Lake Mead storage that would violate this space requirement, the rule computes the additional release necessary to maintain that space.

January through July Operation

The flood control policy requires that the maximum forecast be used where that forecast is defined as the estimated inflow volume that, on average, will not be exceeded 19 times out of 20 (a 95 percent non-exceedance). The rule first computes the inflow forecast to Lake Mead by taking the Lake Powell forecast (**Section A.6.2**, *Lake Powell Inflow Forecast*) and adds the long-term, average tributary inflows between Lake Powell and Lake Mead. The maximum forecast is then estimated by adding an additional volume (the "forecast error term") to that inflow forecast. The forecast error term (in maf) is provided in **Table A-10**, taken from the original CRSS data.

Table A-10
Lake Mead January through July Forecast Error Forecast

Forecast Period	Forecast Error Term (maf)
January – July	4.980
February – July	4.260
March – July	3.600
April – July	2.970
May – July	2.525
June – July	2.130
July – July	0.750

The Field Working Agreement defines an iterative algorithm by which the current month's release (in cfs) is determined. Certain release levels are specified, as listed in **Table A-11**.

Table A-11
Lake Mead Flood Control Release Levels

Release Level	Release (cfs)	Description
1	19,000	Parker Powerplant capacity
2	28,000	Davis Powerplant capacity
3	35,000	Hoover Powerplant capacity (in 1987)
4	40,000	Approximate maximum flow non-damaging to streambed
5	73,000	Hoover Dam controlled discharge capacity

The flood control release needed for the current month is determined by:

$$
\begin{aligned}
&release\ needed\ for\ the\ current\ month \\
&= maximum\ forecast\ inflow \\
&- current\ storage\ space\ in\ Lake\ Powell\ (below\ the\ live\ capacity\ of\ 23{,}313{,}829\ af) \\
&- current\ storage\ space\ in\ Lake\ Mead\ (below\ the\ live\ capacity\ of\ 27{,}620{,}000\ af) \\
&+ 1.5\ maf\ (exclusive\ space) \\
&- evaporation\ and\ bank\ storage\ losses\ from\ Lake\ Powell\ and\ Lake\ Mead \\
&- Southern\ Nevada\ depletion\ - V_{t-July})
\end{aligned}
$$

where V_{t-July} is the future volume of water released, assuming a release level from **Table A-11** for the current month through July.

If the computed release for the current month is greater than that assumed for the future months, the future level is increased, and the current month release is re-computed. The computation stops once the computed release for the current month is less than or equal to that assumed for the future months. If the computed release is greater than the previously assumed level, that release is used for the current month; otherwise, the previously assumed level is used. The rule sets Lake Mead's release to the flood control release if it is greater than the release previously computed to meet downstream demands.

Space Building (August to December)

The flood control policy states the flood control storage space (in maf) in Lake Mead (storage below elevation 1,229 feet) required at the beginning of each month from August through January, as listed in **Table A-12**.

Table A-12
Lake Mead Flood Control Required Storage Space

Date	Required Storage Space (maf)
August	1.50
September	2.27
October	3.04
November	3.81
December	4.58
January	5.35

However, these targets may be reduced to the minimum of 1.5 maf in each month if additional space is available upstream in live storage. Certain upstream reservoirs are specified with a maximum creditable space (in maf) that can be applied towards the total required flood control space. The creditable storage space allowed for each of these reservoirs is listed in **Table A-13**.

Table A-13
Lake Mead Flood Control Maximum Creditable Storage Space

Reservoir	Maximum Creditable Storage Space (maf)
Powell	3.8500
Navajo	1.0359
Blue Mesa	0.7485
Flaming Gorge plus Fontenelle	1.5072

In each month (July through December), if the release computed to meet downstream demands results in an end-of-month Lake Mead storage that would violate the space requirement adjusted for upstream storage, the rule computes the additional release necessary to maintain that space. However, these releases are constrained to be less than or equal to 28,000 cfs.

Flood Control Surplus

If the modeled January 1 system volumes projects Hoover Dam flood control releases based on the Field Working Agreement between Reclamation and the USACE for the flood control operation of Hoover Dam and Lake Mead (USACE 1982), the model assigns the Full Surplus schedules to Metropolitan Water District (MWD), Southern Nevada Water Authority (SNWA), Central Arizona Project (CAP), Imperial Irrigation District, and Coachella Valley Water District (CVWD). In addition, the model assigns an additional delivery of up to 200 kaf to Mexico. All other diversion points remain at Normal schedules.

Infrastructure Constraints at Low Elevations

Lake Mead monthly releases can be constrained due to physical limitations at Hoover Dam. If Lake Mead is below approximately 950 feet in any month, releases are assumed to be constrained to the capacity of the two outlet works.

The capacity of the outlet works varies with the elevation of Lake Mead; the higher the pool elevation, the higher the potential release through the outlet works. CRSS computes the maximum monthly release based on the Lake Mead elevation using **Table A-14** and interpolates for the capacity between elevations.

Table A-14
Mead Outlet Capacity

Pool elevation (feet)	Capacity per 2 Outlet Work (cfs)	Capacity for 4 Outlet Works (cfs)
895	0	0
900	4,800	9,600
925	5,400	10,800
950	6,000	12,000
975	6,600	13,200

Dead Pool-Related Reductions

Dead pool-related reductions occur when Lake Mead is unable to release the volume of water needed to satisfy all downstream demands due to infrastructure or water availability constraints. Dead pool-related reductions are modeled on a monthly basis and for modeling purposes only, are assumed to be distributed using the priority-based shortage scheme; no alternative included any specific criteria or methodology for the distribution of dead pool-related reductions. The following sections describe the assumptions and implementation of the priority-based shortage scheme in CRSS. The implementation was designed to reflect the method described in **Appendix C**. Dead pool-related reductions also follow the **Appendix C** method; however, these reductions are applied at the monthly level because the associated reduction volumes are not known at the beginning of the year, unlike the shortage volumes in alternatives triggered by Lake Mead or other system conditions.

Conservation Activity

All ongoing conservation activities are assumed to be canceled from the month of the first occurrence of a dead pool-related reduction throughout the remainder of the calendar year. In Nevada, Tributary Conservation creation, which occurs in the reaches above Lake Mead, is assumed to be delivered to SNWA for the remainder of the calendar year.

Dead Pool-Related Reductions Volume Computation

After the cancellation of all conservation activity, the dead pool-related reduction volume is computed as the desired release from Lake Mead, i.e., the release that would be made if there were no infrastructure or water availability constraints, minus the volume of water Lake Mead is able to release.

The desired release aims to satisfy all demands that cannot be satisfied via Lower Basin inflows and the releases made from Lake Mohave and Lake Havasu and are calculated as:

$$Desired\ Release = \sum DesiredLBDepl + \sum \Delta LBStorage + \sum \Delta LBEvap - \sum LB\ Inflows$$

where:

DesiredLBDepl = Current month's desired depletions for all water users in the Lower Division States and Mexico, including miscellaneous uses and losses, after adjustments have been made for shortages

$\Delta Storage$ = Sum of the current month's change in storage for Lake Mohave and Lake Havasu

$\Delta Evap$ = Sum of the current month's evaporation for Lake Mohave and Lake Havasu

LB Inflows = Sum of the current month's Lower Basin inflows from the Davis, Alamo, Parker, and Imperial natural flow sites and the Arizona forebeared return flows

Dead Pool-Related Reduction Distribution

Dead pool-related reductions are dynamically applied to water users in the Lower Division States and Mexico based on the current month's desired depletions after adjustments have been made for shortage and existing other assumptions (e.g., shortage, system conservation, fallowing, etc.). Although it draws directly from Lake Mead, SNWA is assumed to be included in the group of water users that dead pool-related reductions are distributed to. CRSS water users that represent other

system losses, e.g., excess flows to Mexico are represented as a water user, are assumed to not be in the users that dead pool-related reductions are distributed to.

Dead pool-related reductions are assumed to use the Lower Basin-wide priority scheme (see **Appendix C** for details), which follows an approximation of the Lower Basin priority system. This scheme is implemented in CRSS using three stages, described in detail below. The assumed CRSS water users' priorities[12] are shown in **Attachment A2**. All water users' desired depletion in each stage is shorted to zero before progressing to the next stage. The three stages are:

Stage 1: Arizona Priority 4 water users and Nevada Stage 1

Stage 2: All remaining water users who do not hold present perfected rights (PPR), which includes Arizona Priorities 4, 3, and 2, California Priorities 4, 3b, 3a, 2, and 1, and Nevada Priorities 8, 7, 4, and 2.

Stage 3: All PPR water users, shorted by priority date (junior to senior)

Mexico is not included in the stages but does is assumed to be included in the distribution of dead pool-related reductions[13]. The portion of the total dead pool-related reduction applied to Mexico is assumed to be proportional to their desired depletions compared to total Lower Basin depletions in each month and is calculated as:

$$MXDeadPoolReduc\% = \frac{Desired\ Depletion_{MX}}{Desired\ Depletion_{MX} + \sum Desired\ Depletions_{LDS\ Contractors}}$$

where:

$Desired\ Depletion_{MX}$ = Desired depletion of the Mexico water user
$Desired\ Depletions_{LDS\ Contractors}$ = Desired depletions of the Lower Division State contractor water users

When distributing the dead pool-related reductions, CRSS first calculates Mexico's assumed portion of dead pool-related reduction by multiplying *MXDeadPoolReduc%* by the total dead pool-related reduction volume. The remaining dead pool-related reduction is then assigned to the Lower Division States and distributed through each stage of reductions until the full volume has been met.

To distribute dead pool-related reductions within the Lower Division States, CRSS computes the water available in each stage and determines the maximum stage that will be impacted by the dead pool-related reduction. For example, if there were 100 kaf of desired depletions in Stage 1, 500 kaf of desired depletions in Stage 2, and 200 kaf of desired depletions in Stage 3, and the dead pool-

[12] There are several CRSS "water users" that aggregate multiple real-world users. In those cases, the assumed priority used in CRSS may not match the priority of all users; the assumed priority is chosen as a modeling simplification. The shortage allocation model provides more detail on the distribution of shortages (**Appendix C**).

[13] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

related reduction was 300 kaf, the maximum stage impacted would be Stage 2. In this example, Stage 1 would satisfy 100 kaf of the dead pool-related reduction and Stage 2 would satisfy the remaining 200 kaf of dead pool shortage, with 300 kaf still available for use to users in the Stage 2 group.

When CRSS has determined the maximum stage that the dead pool-related reduction will impact, all water users with water use in the prior stages have their depletion set to 0 (i.e., fully reduced to meet the dead pool-related reduction). The remaining Lower Division State dead pool-related reduction is computed by subtracting off the total desired depletions for all stages up to the maximum stage, e.g., total desired depletions for Stage 1 and Stage 2 water users for a dead pool-related reduction that is computed to affect Stage 3 water users.

The remaining dead pool-related reduction is then applied to the water users with use included in the maximum stage. The following sections describe how the dead pool-related reduction is divided among water users in each stage. In each stage, all water of equal priority is divided proportionally using the following formula:

$$Proportion\ \%_{Specific\ Water\ User/Group} = \frac{\sum Desired\ Depletion_{Specific\ Water\ User/Group}}{\sum Desired\ Depletion_{All\ Applicable\ Water\ Users}}$$

Stage 1 Dead Pool-Related Reductions

Stage 1 dead pool-related reductions are applied to the Arizona Priority 4 water users and Nevada water users. Stage 1 dead pool-related reduction ends when Arizona Priority 4 uses are reduced to zero. Nevada's maximum stage 1 dead pool related reductions is calculated as:

$$NV_{Stage\ 1\ max} = AZ_{P4}\left(\frac{\sum NV_{non-PPR}}{\sum AZ_{non-PPR} + \sum CA_{non-PPR} + \sum NV_{non-PPR}}\right)$$

where:

$NV_{Stage\ 1\ max}$ is Nevada's maximum stage 1 dead pool-related reduction
AZ_{P4} = Desired depletions from all Arizona Priority 4 water users and Arizona's maximum stage 1 dead pool-related reduction
$AZ_{non\text{-}PPR}$ = Desired depletions from all Arizona water users who do not have PPR
$CA_{non\text{-}PPR}$ = Desired depletions from all California water users who do not have PPR
$NV_{non\text{-}PPR}$ = Desired depletions from all Nevada water users who do not have PPR

The ratio between the Nevada and Lower Division State non-PPR water for the shortage allocation model is roughly 7 percent; however, for modeled dead pool-related reductions this ratio does not always hold. Policy actions prior to the determination of dead pool-related reduction may have already shorted some non-PPR water users, changing the distribution of non-PPR desired depletions between Nevada and the rest of the Lower Division States. Additionally, dead pool-related reduction is a monthly computation, not an annual computation, so different monthly distributions can change the ratio between the Nevada non-PPR water users and the Lower Division State non-PPR water users.

The Stage 1 dead pool-related reduction is distributed to Arizona and Nevada proportional to their maximum stage 1 reduction volume, where Arizona's maximum stage 1 dead pool-related reduction

is their total P4 desired depletion. The volumes of dead pool-related reductions for Arizona and Nevada are:

$$AZ_{Stage\ 1} = DPRR * \frac{AZ_{P4}}{AZ_{P4} + NV_{Stage\ 1\ max}}$$

$$NV_{Stage\ 1} = DPRR * \frac{NV_{Stage\ 1\ max}}{AZ_{P4} + NV_{Stage\ 1\ max}}$$

where:

$AZ_{Stage\ 1}$= Arizona's portion of the Stage 1dead pool-related reduction
$NV_{Stage\ 1}$ = Nevada's portion of the Stage 1 dead pool-related reduction
$DPRR$ = the dead pool-related reduction volume

Nevada's Stage 1 dead pool-related reduction ($NV_{Stage\ 1}$) is distributed as per the state priority system from junior to senior priority, excluding the PPR water users. The shortages are first applied to the Priority 8 water users until either the Nevada portion of dead pool-related reduction is satisfied, or all Nevada Priority 8 water users have been completely shorted. If all Priority 8 water users are fully shorted and there is still a portion of the Stage 1 dead pool-related reduction remaining, then Priority 7 water users are reduced, continuing in this manner until Nevada's Stage 1 dead pool-related reduction volume has been distributed. When there are multiple users with the same priority, the dead pool-related reduction is distributed proportionally to users with the same priority.

Arizona's Stage 1 dead pool-related reduction ($AZ_{Stage\ 1}$) is distributed proportionally between all Arizona Priority 4 water users.

Stage 2 Dead Pool-Related Reductions

Stage 2 dead pool-related reductions are applied to all remaining non-PPR water users. The dead pool-related reduction is distributed to each state proportional to their remaining non-PPR desired depletions after the Stage 1 dead pool-related reductions have been applied.

Within each state, dead pool-related reductions are distributed from the most junior to the most senior priority water users excluding PPR water users. Dead pool-related reductions are first applied to the most junior priority group (Arizona Priority 3[14], California Priority 4, and Nevada Priority 8) until either the state's assigned dead pool-related reduction volume is met or all users within the priority group have been fully reduced. If the priority group is fully reduced and there is remaining dead pool-related reduction, then reductions are distributed to the next most junior priority group continuing sequentially until the state's total dead pool-related reduction obligation has been satisfied. Within each priority group, the dead pool-related reduction is applied proportionally among all water users in that group.

[14] Arizona Priority 2 and 3 are modeled as co-equal in the Shortage Allocation Model, and should be modeled as such in CRSS to be consistent with the Shortage Allocation Model.

Stage 3 Dead Pool-Related Reductions

Dead pool-related reductions in Stage 3 are applied to PPR water users using a priority list organized by priority date such that the junior water users are fully shorted before the senior water users are impacted. CRSS does not have a water user to represent each Lower Basin PPR contract and has 8 water users that represent the aggregate of several PPR contracts. When PPR contracts are aggregated to one water user, the water user is placed on the PPR list as the priority date of the PPR contract with the highest volume diversion entitlement.

Remaining Dead Pool-Related Reductions

There are very few instances when the dead pool-related reduction volume is greater than the sum of the desired use from all contract water users in the Lower Division States and Mexico. When this occurs, all water users in the Lower Basin and Mexico are fully shorted (i.e., 0 af of depletions that month), and so CRSS must short the water users that represent other uses and losses in the Lower Basin, such as the assumed excess flows to Mexico.

A.7.2 CCS Comparative Baseline

The CCS Comparative Baseline assumes that existing agreements, including the 2007 Interim Guidelines, 2017 Minute 323, and 2019 DCP continue through the analysis period (2027-2060). Lake Mead operations and Lower Basin conditions are set based on the previous EOCY pool elevation at Lake Mead. This is a modeling simplification, rather than using an August based projection of December 31 conditions, as specified in the 2007 Interim Guidelines.

Surplus

The Lower Basin is assumed to operate in a Surplus Condition if the Lake Mead elevation starts the year above 1,145 feet or if it exceeds an elevation that would trigger space-building or flood control releases pursuant to the 1984 Field Working Agreement between Reclamation and the USACE (Flood Control surplus; described in **Section A.7.1**, *Lake Mead/Hoover Dam Flood Control*) anytime in the year. There are two additional levels of Surplus in CCS Comparative Baseline: Domestic and Quantified. Increased deliveries to Mexico due to high reservoir conditions are assumed to occur and are consistent with volumes prescribed in Minute 323 Section II.

Domestic Surplus

A Domestic Surplus is determined if the Lake Mead elevation is above 1,145 feet and below the elevation that triggers a Quantified Surplus. Under a Domestic Surplus, depletion schedules are modified in the Lower Division States by the surplus volume as follows:

- For use by MWD, 250,000 af per year in addition to the amount of California's basic apportionment available to MWD.
- For use by SNWA, up to 100,000 af per year in addition to the amount of Nevada's basic apportionment available to SNWA.
    - SNWA is assumed to only take delivery of the volume of surplus water needed to satisfy their demands that exceed apportionment (see Appendix B)
- For use in Arizona, 100,000 af per year in addition to the amount of Arizona's basic apportionment available to Arizona Contractors.

These volumes are reduced by the same volume that Mexico's delivery is increased as described in a subsequent section. The reduction volume is split proportionally among these three users.

Quantified Surplus

A Quantified Surplus is assumed to occur when water needs to be delivered to reduce the risk of potential reservoir spills based on the 70R Strategy (described below). Under a Quantified Surplus, depletion schedules are modified in the Lower Division States consistent with the 2007 Interim Guidelines Section 2.B.3.

Under the 70R Strategy, a surplus condition is based on the system space requirement at the beginning of each year. Based on the 70th percentile historical runoff, a normal 7.5 maf delivery to the Lower Division States, the Upper Basin scheduled use, and Lake Powell and Lake Mead volumes at the beginning of the year, the volume of water in excess of the system space requirement at the end of the year is estimated. If that volume is greater than zero, a Surplus is declared. The quantity of the surplus volume (SurVol) is computed as follows:

$$SurVol = (PowellStorage + MeadStorage - maxStorage + ConsMechVol) * (1 + aveBankStorCoef) + runoff - UBDemand - LBDemand$$

where:

Powell Storage = Lake Powell storage at the beginning of the year
Mead Storage = Lake Mead storage at the beginning of the year
maxStorage = maximum combined storage of Lake Powell and Lake Mead that will meet the system space requirement at the beginning of the year, assuming 30% of that requirement will be met by the reservoirs upstream of Lake Powell (computed as live capacity of Lake Powell and Lake Mead – 70% * Lake Mead space requirement at the beginning of the year)
ConsMechVol = previous year's conservation mechanism volume[15]
aveBankStorCoef = average of Lake Powell and Lake Mead bank storage coefficients
runoff = assumed percentile runoff (70%) based on the historical record of 1931 through the previous year
UBDemand = Upper Basin depletion scheduled for the year (estimated using the logistic regression described in **Section A.6.2** + the estimated evaporation loss in the Upper Basin. The estimated evaporation is the sum of the previous year's evaporation at Lake Powell and calculated evaporation based on target storage at all other Upper Basin reservoirs except McPhee and the TMD reservoir which take the average of the previous 5 years of evaporation.
LBDemand = sum of depletions below Lake Powell[16] + the evaporation losses in the Lower Basin (previous year's evaporation at Lake Mead and calculated evaporation at

[15] In the Enhanced Coordination and Supply Driven Alternatives only, the modeled logic erroneously excluded new conservation mechanism volumes.
[16] The modeled logic erroneously excluded 378,700 af of MWD's annual scheduled depletion when calculating the sum of depletions below Lake Powell.

Lake Mohave and Lake Havasu, based on target storage) – average of the last 5-years of gains between Lake Powell and Lake Mead – average gains below Lake Mead

Once the quantity of surplus volume is known, the model computes each state's share (50 percent to California, 46 percent to Arizona, and 4 percent to Nevada). The model then assigns the Full Domestic Surplus schedules to MWD and SNWA. Arizona's share of the surplus is assigned to CAP, up to their Full Surplus schedule. If surplus water is still available for California, up to 300 kaf is made available to Imperial Irrigation District and CVWD.

Minute 323 Distribution of Flows Under High Elevation Reservoir Conditions

Distribution of flows to Mexico under high-elevation reservoir conditions is modeled based on the volumes in Minute 323 Section II, when the Lake Mead EOCY pool elevation is at or above 1,145 feet. Mexico's annual delivery is increased by the volumes shown in **Table A-15**.

Table A-15
Minute 323 Annual Increased Delivery To Mexico

Mead Elevation (ft)	Volume (af)
<1,145	0
1,145 to 1,170	40,000
1,170 to 1,200	55,000
>1,200	80,000

Normal Conditions

The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,075 feet and below 1,145 feet. DCP contributions are assumed to continue when Lake Mead is less than or equal to 1,090 feet. The modeled DCP contributions are described in the following section.

Shortage Conditions and Contributions

2007 Interim Guidelines Shortages

A 2007 Interim Guidelines Lower Basin Shortage Condition is modeled if the Lake Mead pool elevation is less than or equal to 1,075 feet. A rule solves for the Shortage Condition in January by comparing Lake Mead's previous EOCY pool elevation to defined pool elevations, as shown in **Table A-16**. The annual shortage volumes are distributed between states as shown in **Table A-16**.

Table A-16
2007 Interim Guidelines Lower Division State Shortage Volumes

Lake Mead Elevation (feet)	Arizona Shortage (af)	Nevada Shortage (af)	Total Shortage (af)
>1,075	0	0	0
1,075 to 1,050	320,000	13,000	333,000
<1,050 to 1,025	400,000	17,000	417,000
<1,025	480,000	20,000	500,000

Minute 323 Distribution of Flows Under Low Elevation Reservoir Conditions

Minute 323 defines annual reductions to Mexico under low-elevation reservoir conditions based on the Lake Mead EOCY pool elevation. **Table A-17** shows the modeled reductions to Mexico.

Table A-17
Mexico Minute 323 Reductions

Lake Mead Elevation (feet)	Mexico Reduction (af)
>1,075	0
1,075 to 1,050	50,000
<1,050 to 1,025	70,000
<1,025	125,000

2019 Drought Contingency Plan and Binational Water Scarcity Contingency Plan

CRSS models the 2019 DCP contributions in accordance with Exhibit 1 to the Lower Basin DCP agreement and the Binational Water Scarcity Contingency Plan (BWSCP) contributions in accordance with Minute 323. The contribution volumes (**Table A-18**) are based on the Lake Mead previous EOCY pool elevation. For modeling purposes, DCP contributions can be made through conversion of existing Intentionally Created Surplus (ICS), simultaneous ICS creation and conversion to DCP-ICS, and/or reducing depletions to create system water. CRSS ICS assumptions for CCS Comparative Baseline are described in **Appendix B**.

Table A-18
2019 DCP and Minute 323 BWSCP Contribution Volumes

Lake Mead Elevation (feet)	DCP (1,000 af)			Minute 323 BWSCP (1,000 af)
	Arizona	Nevada	California	
>1,090	0	0	0	0
1,090 – 1,075	192	8	0	41
1,075 – 1,050	192	8	0	30
<1,050 – >1,045	192	8	0	34
1,045 – >1,040	240	10	200	76
1,040 – >1,035	240	10	250	84
1,035 – >1,030	240	10	300	92
1,030 – 1,025	240	10	350	101
<1,025	240	10	350	150

Shortage Distribution

The shortage and DCP contributions are distributed to the Lower Division States as shown in **Table A-16** and **Table A-18**. In Nevada, the Southern Nevada Water Providers water user incurs the entire shortage volume and DCP contribution. The Nevada state apportionment is reduced by the shortage volume, so the Southern Nevada Water Providers depletion requested is not affected by the shortage volume until their demand is closer to the state apportionment (see **Appendix M** for assumed depletion schedules). In California, the DCP contribution is split such that 93 percent is applied to MWD and 7 percent to CVWD. In Arizona, the shortage volume is distributed

proportionally between Priority 4 water users and DCP contribution volumes are made by the CAP water user.

A.7.3 No Action Alternative

The Lake Mead operations and Lower Basin conditions for the No Action Alternative are assumed to be determined based on the previous EOCY pool elevation at Lake Mead.

Surplus

The No Action Alternative models two levels of surplus for the Lower Basin: Quantified Surplus and Flood Control Surplus. The Quantified Surplus modeling assumptions under the No Action Alternative are identical to CCS Comparative Baseline (**Section A.7.2**). Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

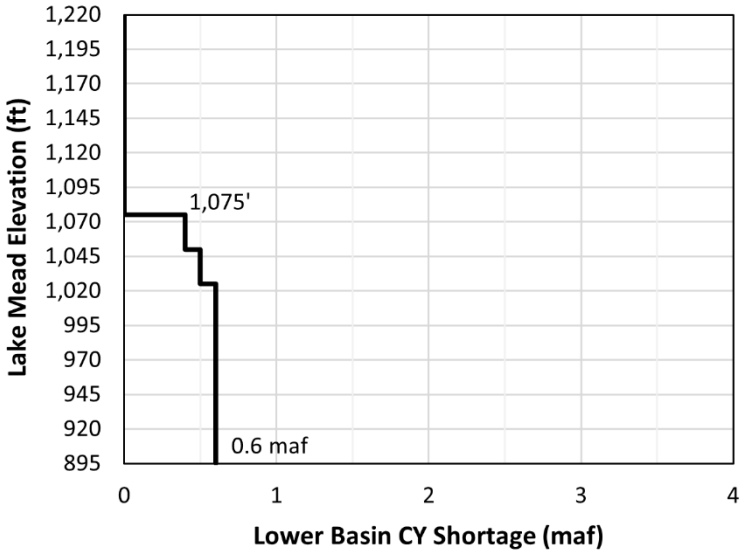
Normal Conditions

The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,075 feet and not in a surplus condition.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the No Action Alternative when Lake Mead ended the previous year below 1,075 feet. The shortage volumes by Lake Mead elevation are shown in **Figure A-7** and are the same as the total Lower Basin volume under the 2007 Interim Guidelines Shortages, not including DCP and BWSCP contributions, in CCS Comparative Baseline.

Figure A-7
Shortage Guidelines to Reduce Deliveries from Lake Mead, No Action Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the U.S.-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty) or to

> represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

The No Action Alternative distributes shortages using the priority system. The following describes the assumptions and implementation of the priority-based shortage scheme in CRSS. The implementation was designed to reflect the method described in **Appendix C**. Shortages are applied to water users in the Lower Division States and Mexico based on the current year's scheduled demand. The priority-based shortage scheme follows an approximation of the priority system (see **Appendix C** for details). It is implemented in CRSS using three stages, described in detail below. The assumed CRSS water users' priorities[17] are shown in **Attachment A2**. All water users' scheduled demand in each stage is shorted to zero before progressing to the next stage. The three stages are:

Stage 1: Arizona Priority 4 water users and Nevada Stage 1

Stage 2: All remaining water users who do not hold PPR, which includes Arizona Priorities 4, 3, and 2, California Priorities 4, 3b, 3a, 2 and 1, and Nevada Priorities 8, 7, 4, and 2

Stage 3: All PPR water users, shorted by priority date (junior to senior)

Mexico is not included in the stages but is assumed to be included in the distribution of shortages. Mexico's portion of the total Lower Basin shortage is assumed to be 16.67 percent, proportional to Mexico's apportionment relative to the combined apportionments of the Lower Division States and Mexico[18].

In CRSS, Mexico's assumed portion of the total Lower Basin shortage is computed. The remainder of the shortage is then distributed to the Lower Division States using a modeling estimation of the priority system as described above. This is similar to the method used to distribute dead pool-related reductions (**Section A.7.1**, *Dead Pool-Related Reductions*), except that the shortages are distributed at an annual scale and are based on the input depletion schedules/state apportionments whereas dead pool-related reductions are distributed monthly and rely on desired use.

A.7.4 Basic Coordination Alternative

The Lake Mead operations and Lower Basin conditions for the Basic Coordination Alternative are assumed to be based on the previous EOWY pool elevation at Lake Mead.

[17] There are several CRSS "water users" that aggregate multiple real-world users. In those cases, the assumed priority used in CRSS may not match the priority of all users; the assumed priority is chosen as a modeling simplification. **Appendix C** provides more details on the distribution of shortages.

[18] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

Surplus

The Surplus method under the Basic Coordination Alternative is modeled identically to that of the No Action Alternative.

Normal Conditions

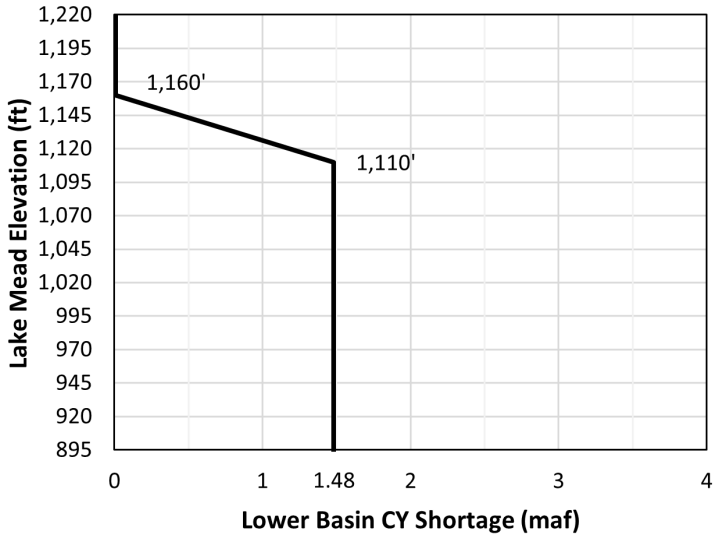
The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,160 feet and not in a surplus condition.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Basic Coordination Alternative when Lake Mead ended the previous water year below 1,160 feet. The shortage zones are summarized below and shown in **Figure A-8**.

- When Lake Mead is at or below elevation 1,160 feet and at or above 1,110 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,160 feet increasing linearly to 1.48 maf at 1,110 feet.
- When Lake Mead is below elevation 1,110 feet, a shortage of 1.48 maf would be imposed for that year.

Figure A-8
Shortage Guidelines to Reduce Deliveries from Lake Mead, Basic Coordination Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution
Shortage volumes in the Basic Coordination Alternative are distributed among mainstream Lower Colorado River users based on the priority system, identical to the No Action Alternative.

A.7.5 Enhanced Coordination Alternative

The Lake Mead operations and Lower Basin conditions for the Enhanced Coordination Alternative are assumed to be based on the previous EOWY sum of effective storage[19] in Lake Powell and physical storage in Lake Mead. The combined storage percentage is computed as:

$$S_{eff} = \frac{P_{EOWY} - C_{UB} + M_{EOWY}}{P_{max} + M_{max}}$$

where:

S_{eff} = the total Lake Powell effective storage and Lake Mead physical storage as a percentage of capacity
P_{EOWY} = Lake Powell physical storage at the end of the previous water year
C_{UB} = the total volume of conserved water in Lake Powell
M_{EOWY} = Lake Mead physical storage at the end of the previous water year
P_{max} = Lake Powell live capacity (23.31 maf)
M_{max} = the Lake Mead live capacity excluding exclusive flood control space (26.12 maf)

Surplus

The Surplus method under the Enhanced Coordination Alternative is modeled identically to that of the No Action Alternative.

Normal Conditions

The Lower Basin operates in a Normal Condition if the sum of Lake Powell effective storage and Lake Mead physical storage at the end of the previous water year is above 60 percent and not in a Surplus Condition.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Enhanced Coordination Alternative when the sum of Lake Powell effective storage and Lake Mead physical storage at the end of the previous water year is below 60 percent.

Required shortages could be partially or fully offset by converting previously conserved Upper Basin water, subject to provisions described below. The shortage zones are summarized below and shown in **Figure A-9**.

- When the sum of Lake Powell effective storage and Lake Mead physical storage is equal to or less than 60 percent of combined capacity and greater than or equal to 30 percent combined capacity, a shortage volume would be imposed for that year based on a function

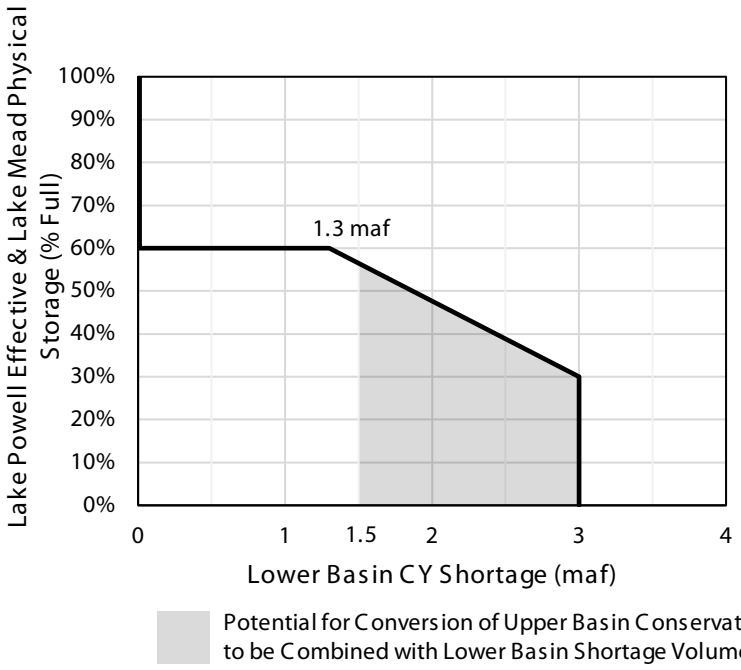
[19] "Effective" storage is calculated as physical storage minus any conserved volume that is held in the respective reservoir(s).

of storage, with 1.3 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 30 percent of capacity.

- When the sum of Lake Powell effective storage and Lake Mead physical storage is less than 30 percent of combined capacity, a shortage volume of 3.0 maf would be imposed for that year.

When Lower Basin shortages are greater than 1.5 maf, a volume equal to one-third of the volume above 1.5 maf would be converted from the Lake Powell conservation pool into system water such that the total of Lower Basin shortages and conversion of Upper Basin water equal the required total shortage volume (i.e., above 1.5 maf, there is a 2-to-1 Lower Basin shortage-to-Upper Basin conversion ratio) If the prescribed 2-to-1 volume is not available in the Lake Powell conservation pool, 100 percent of the available volume would be converted, and the Lower Basin would take the balance of shortages. The Upper Basin conservation pool modeling assumptions are described in **Appendix B**.

Figure A-9
Shortage Guidelines to Reduce Deliveries from Lake Mead, Enhanced Coordination Alternative



Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

Shortages in the Enhanced Coordination Alternative are assumed to be distributed pro rata among mainstream Lower Colorado River users independent of state. The CRSS implementation of the pro rata shortage approach distributes the shortage volume proportionally to all Lower Division State water users and Mexico[20] using the equation:

$$Water\ User\ Proportion\ \% = \frac{Annual\ Depletion\ Schedule_{\ Water\ User}}{\sum Annual\ Depletion\ Schedule_{\ All\ Applicable\ Water\ Users}}$$

where:

$Annual\ Depletion\ Schedule_{Water\ User}$ = Annual depletion schedule volume for the water user being shorted

$\sum Annual\ Depletion\ Schedule_{All\ Applicable\ Water\ Users}$ = Sum of the annual depletion schedules for all contract water users in the Lower Basin and Mexico (i.e., 9.0 maf)

A.7.6 Maximum Operational Flexibility Alternative

The Lake Mead operations and Lower Basin conditions for the Maximum Operational Flexibility Alternative are assumed to be based on the previous EOWY total system effective storage (Lake Powell, Flaming Gorge, Blue Mesa, and Navajo, Lake Mead, Lake Mohave, and Lake Havasu) and a climate response indicator[21]. The Conservation Reserve, which is a storage mechanism for conserved water in Lake Powell and/or Lake Mead, is assumed to be subtracted from the physical storage so that it does not affect Lake Mead operations. The Conservation Reserve modeling assumptions are described in **Appendix B**. The EOWY total system effective storage as a percentage is computed as:

$$S_{eff} = \frac{(\sum_{r \in R} r_{EOWY}) - C_{CR}}{\sum_{r \in R} r_{max})}$$

where:

S_{eff} = the total system effective storage as a percentage of capacity
R = the set of system reservoirs: Lake Powell, Flaming Gorge, Blue Mesa, and Navajo, Lake Mead, Lake Mohave, and Lake Havasu
r_{EOWY} = the EOWY physical storage at the reservoir
r_{max} = the assumed maximum capacity of the reservoir from **Table A-2**
C_{CR} = the total volume of conserved water in the Conservation Reserve

[20] Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[21] For modeling purposes, the previous 3-year average Lees Ferry natural flow is used.

Surplus

The Maximum Operational Flexibility Alternative assumes that Surplus Conditions only occur during Flood Control Surplus. Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

Normal Conditions

The Lower Basin operates in a Normal Condition if the total system effective storage is greater than 60 percent and Lake Mead is not in a Flood Control Surplus Condition.

Shortage Condition

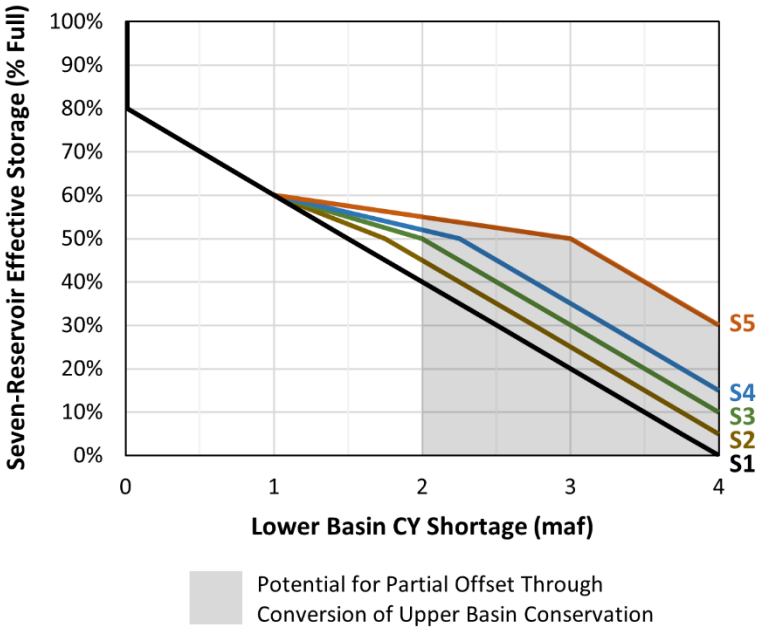
A Shortage Condition is modeled in the Lower Basin under the Maximum Operational Flexibility Alternative when the total system effective storage is less than 60 percent at the end of the previous water year. The shortage zones and previous 3-year average Lees Ferry natural flow values are summarized below and shown in **Figure A-10** and **Table A-19**.

- When total system effective storage is at or below 80 percent of capacity and at or above 60 percent of capacity, a shortage volume would be imposed for that year based on a function of storage, with 0.0 maf of shortage at 80 percent of capacity increasing linearly to 1.0 maf at 60 percent of capacity.
- When total system effective storage is at or below 60 percent of capacity and at or above 50 percent of capacity, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.5 maf at 50 percent of capacity (S1 curve in **Figure A-10**).
    - If the previous 3-year average Lees Ferry natural flow is less than 14.0 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.75 maf at 50 percent of capacity (S2 curve in **Figure A-10**).
    - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.0 maf at 50 percent of capacity (S3 curve in **Figure A-10**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.25 maf at 50 percent of capacity (S4 curve in **Figure A-10**).
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 50 percent of capacity (S5 curve in **Figure A-10**).

- When total system effective storage is 50 percent of capacity or less, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.5 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 0 percent of capacity (S1 curve in **Figure A-10**).
    - If the previous 3-year average Lees Ferry natural flow is less than 14 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.75 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 5 percent of capacity (S2 curve in **Figure A-10**). Below 5 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 10 percent of capacity (S3 curve in **Figure A-10**). Below 10 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.25 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 15 percent of capacity (S4 curve in **Figure A-10**). Below 15 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 3.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 30 percent of capacity (S5 curve in **Figure A-10**). Below 30 percent of capacity, a shortage of 4.0 maf would be imposed for that year.

Upper Basin users' conserved water is assumed to be converted to system water based on the shortage curve in **Figure A-10**. When Lower Basin shortages are greater than 2.0 maf, the volume above 2.0 maf would be converted from Upper Basin users' Conservation Reserve water to system water, subject to availability in the Reserve. The required Lower Basin shortage volume would be reduced by whatever volume of previously conserved Upper Basin water is converted. The Upper Basin Conservation Reserve modeling assumptions are described in **Appendix B**.

Figure A-10
Shortage Guidelines to Reduce Deliveries from Lake Mead, Maximum Operational Flexibility Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table A-19
Shortage Curves and Relevant Conditions, Maximum Operational Flexibility Alternative

Shortage Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Shortage Increase Compared to S1 Curve at 50% Full (kaf)
S1	≥ 14	N/A
S2	< 14 to ≥ 12	250
S3	< 12 to ≥ 10	500
S4	< 10 to ≥ 8	750
S5	< 8	1,500

Shortage Distribution

Shortages in the Maximum Operational Flexibility Alternative are assumed to be based on priority as described in the Lower Basin Priority method of the Supply Driven Alternative (refer to **Section A.7.7**, *Shortage Condition*).

A.7.7 Supply Driven Alternative

The Lake Mead operations and Lower Basin conditions for the Supply Driven Alternative are assumed to be based on the July 31 effective pool elevation at Lake Mead.

Surplus

The Supply Driven Alternative assumes three levels of surplus for the Lower Basin: Domestic Surplus, Quantified Surplus and Flood Control Surplus. Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

Domestic Surplus

Domestic Surplus is assumed to occur anytime the July 31 Lake Mead effective elevation is at or above 1,165 feet and not in a Quantified or Flood Control Surplus Condition. Surplus volumes are assumed to be distributed as shown in **Table A-20**, with Arizona's volume delivered to CAP, California's volume delivered MWD, and Nevada's volume delivered SNWA in CRSS.

Table A-20
Lower Basin Domestic Surplus Assumptions

Mead Pool Elevation (feet)	Arizona Surplus (af)	California Surplus (af)	Nevada Surplus (af)	Total US Surplus (af)	Mexico Surplus* (af)	Total (af)
<1,165	0	0	0	0	0	0
1,165	80,000	0	3,333	83,333	16,667	100,000
1,170	160,000	0	6,667	166,667	33,333	200,000
1,175	240,000	0	10,000	250,000	50,000	300,000
1,180	240,000	80,000	13,334	333,334	66,666	400,000
1,185+	240,000	160,000	16,667	416,667	83,333	500,000

*Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

Quantified Surplus

The Quantified Surplus model assumptions are identical to the CCS Comparative Baseline (**Section A.7.2**, *Surplus*, *Quantified Surplus*), except the quantity of surplus volume is assumed to be distributed among states as follows: 41.6 percent to California, 38.33 percent to Arizona, 3.33 percent to Nevada, and 16.67 percent to Mexico[22].

Normal Conditions

The Lower Basin operates in a Normal Condition if the Lake Mead effective elevation is above 1,145 feet and below 1,165 feet.

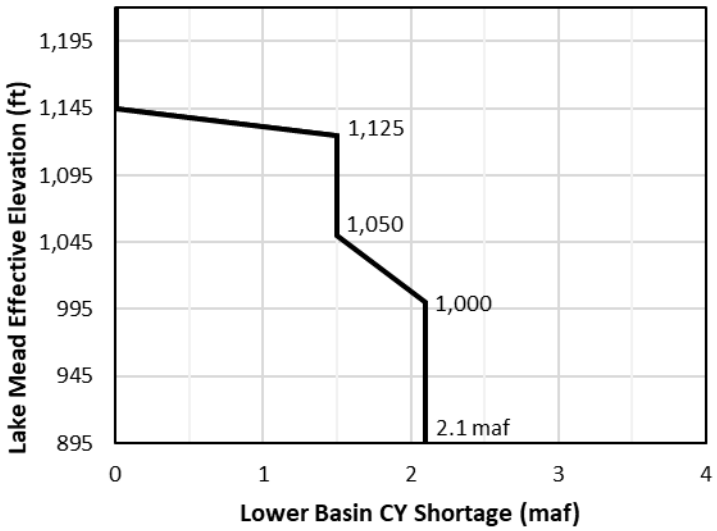
[22] The modeled logic erroneously determines Quantified Surplus as the maximum of the Domestic Surplus schedules developed under the Interim Guidelines and the updated Domestic Surplus logic developed for the Supply Driven Alternative. Instead, it should determine Quantified Surplus as the maximum of the Domestic Surplus allocation and the Quantified Surplus volume calculated using the 70R spill avoidance strategy.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Supply Driven Alternative when the Lake Mead effective elevation on July 31 is below 1,145 feet. The shortage zones are summarized below and shown in **Figure A-11**.

- When Lake Mead effective elevation is at or below 1,145 feet and at or above 1,125 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,145 feet increasing linearly to 1.5 maf at 1,125 feet.
- When Lake Mead effective elevation is at or below 1,125 feet and at or above 1,050 feet, a shortage volume of 1.5 maf would be imposed for that year.
- When Lake Mead effective elevation is at or below 1,050 feet and at or above 1,000 feet, a shortage volume would be imposed for that year based on a function of elevation, with 1.5 maf of shortage at 1,050 feet increasing linearly to 2.1 maf at 1,000 feet.
- When Lake Mead effective elevation is below 1,000 feet a shortage volume of 2.1 maf would be imposed for that year.

Figure A-11
Shortage Guidelines to Reduce Deliveries from Lake Mead, Supply Driven Alternative



Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

Shortage volumes in this alternative are modeled using two different approaches to the distribution of shortages among mainstream Lower Colorado River users:

1. Lower Basin Priority: up to 1.5 maf, intra-state priority using state distributions submitted by Lower Division States; above 1.5 maf, intra-state priority using state distribution based on the CRSS model implementation of priority as described in the No Action Alternative (**Section A.7.3**, *Shortage Condition*, *Shortage Distribution*).

2. Lower Basin Pro Rata: up to 1.5 maf, intra-state pro rata using state distributions submitted by Lower Division States; above 1.5 maf, intra-state pro rata distributed to states proportionally based on unreduced apportionments as described in the Enhanced Coordination Alternative (**Section A.7.5**, *Shortage Condition*, *Shortage Distribution*).

"State distributions" refers to how total shortage volumes up to 1.5 maf are assumed to be distributed in the Lower Basin. **Table A-21** reports the assumed distributions of shortage volumes up to 1.5 maf.

Table A-21
Supply Driven Shortage Distribution Assumptions Submitted by the Lower Division State

Total Shortage (af)	Arizona (af)	California (af)	Nevada (af)	Mexico* (af)
1,500,000	760,000	440,000	50,000	250,000
300,000	240,000	0	9,990	50,010
0	0	0	0	0

*Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

A.7.8 Representative Preferred Alternative

The Lake Mead operations and Lower Basin conditions for the Representative Preferred Alternative are assumed to be based on the December 31 pool elevation at Lake Mead.

Surplus

The Representative Preferred Alternative assumes three levels of surplus for the Lower Basin: Domestic Surplus, Quantified Surplus and Flood Control Surplus. Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

Domestic Surplus

Domestic Surplus model assumptions are identical to the Supply Driven Alternative (**Section A.7.7**, *Surplus*, *Domestic Surplus*), except it is assumed to occur anytime the December 31 Lake Mead elevation is at or above 1,165 feet and not in a Quantified or Flood Control Surplus Condition.

Quantified Surplus

The Quantified Surplus model assumptions are identical to the Supply Driven Alternative (**Section A.7.7**, *Supply Driven Alternative*).

Normal Conditions

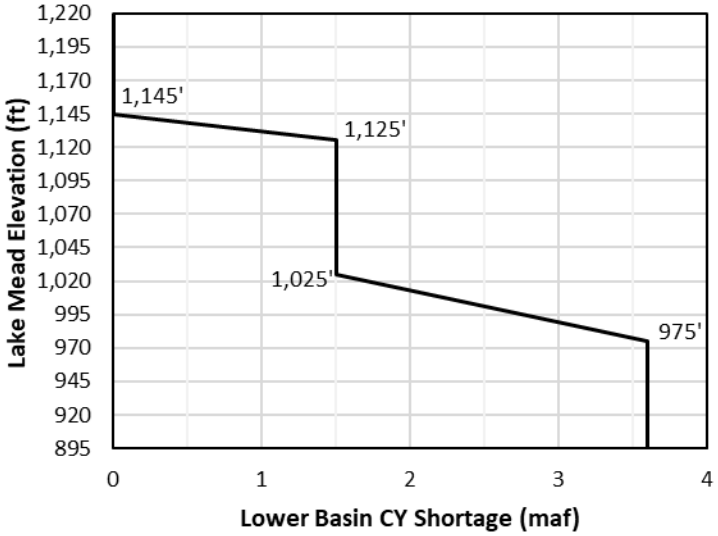
The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,145 feet and below 1,165 feet.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Representative Preferred Alternative when the Lake Mead elevation on December 31 is below 1,145 feet. The shortage zones are summarized below and shown in **Figure A-12**.

- When Lake Mead elevation is at or below 1,145 feet and at or above 1,125 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,145 feet increasing linearly to 1.5 maf at 1,125 feet.
- When Lake Mead elevation is at or below 1,125 feet and at or above 1,025 feet, a shortage volume of 1.5 maf would be imposed for that year.
- When Lake Mead elevation is at or below 1,025 feet and at or above 975 feet, a shortage volume would be imposed for that year based on a function of elevation, with 1.5 maf of shortage at 1,025 feet increasing linearly to 3.6 maf at 975 feet.
- When Lake Mead elevation is below 975 feet a shortage volume of 3.6 maf would be imposed for that year.

Figure A-12
Shortage Guidelines to Reduce Deliveries from Lake Mead, Representative Preferred Alternative



Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United

States policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

Two different approaches for distributing shortages are assumed in the Representative Preferred Alternative. In 2027 and 2028 shortage volumes up to 1.5 maf are distributed using the approach developed by the Lower Division States and shortage volumes above 1.5 maf up to 3.6 maf are distributed using the priority system. These assumptions match the assumptions in the Lower Basin Priority method, as described in the Supply Driven Alternative (**Section A.7.7**, *Shortage Distribution*). Shortage volumes for 2029 through 2060 are distributed among mainstream Lower Colorado River users based on the priority system, identical to the No Action Alternative (**Section A.7.3**, *Shortage Distribution*).

A.8 Lake Mohave and Lake Havasu Operations

Lake Mohave and Lake Havasu are operated to meet user-specified storage targets at the end of each month. These operations remain consistent for all alternatives. The storage targets and the corresponding elevations for Lake Mohave and Lake Havasu are provided in the following sections.

A.8.1 Lake Mohave/Davis Dam

Lake Mohave is operated to meet monthly elevation targets (**Table A-22**). These elevation targets are based on storage space targets set by the USACE for Lower Basin flood control purposes, as well as for endangered species operations developed in conjunction with the U.S. Fish and Wildlife Service.

Table A-22
Lake Mohave Monthly Elevation and Storage Targets

Month	Lake Mohave Target Elevation (feet)	Lake Mohave Target Storage (1,000 af)
January	641.8	1,666
February	641.8	1,666
March	642.5	1,685
April	643.0	1,699
May	643.0	1,699
June	643.0	1,671
July	642.0	1,658
August	642.0	1,658
September	640.0	1,617
October	630.5	1,371
November	635.0	1,486
December	638.7	1,583

A.8.2 Lake Havasu/Parker Dam

Lake Havasu is operated to meet monthly elevation targets (**Table A-23**). These elevation targets are based on storage space targets set by the USACE for Lower Basin flood control purposes, as well as for seasonal needs to meet downstream water demands.

Table A-23
Lake Havasu Monthly Elevation and Storage Targets

Month	Lake Havasu Target Elevation (feet)	Lake Havasu Target Storage (1,000 af)
January	446.5	552
February	446.5	552
March	446.7	555
April	448.7	593
May	448.7	593
June	448.7	593
July	448.0	580
August	447.5	571
September	447.5	571
October	447.5	571
November	447.5	571
December	446.5	552

A.9 Energy Generation

RiverWare™ includes a variety of methods that can be chosen to compute electrical power generation and estimate generation capacity. All methods compute power and energy on a monthly basis. In addition to power and energy, these results can be used to estimate revenue and total economic value of hydropower. The following sections describe the methods used to compute power at Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam.

A.9.1 Glen Canyon Dam

While CRSS includes a RiverWare™ method to compute electrical power generated from Glen Canyon Dam, the power generation data used in **Section 3.15** are computed using Generation Transmission Maximization Model Lite.

If the previous month's elevation is less than 3,490 feet, there is no power or energy generated for the current month. This elevation reflects the minimum power pool elevation at Lake Powell.

A.9.2 Hoover Dam

The method that computes power and energy generated at Hoover Dam assumes two levels of power generation. The lower level of generation occurs at base flow, while the upper level occurs at peak flow. The method computes the fraction of the month that the powerplant is operated at peak flow and base flow. The peak flow is the most efficient flow through the turbines for the current

operating head, while the base flow represents the minimum flow through the turbines to produce energy.

The base flow and corresponding power generation are based on the outflow for the current month. The peak flow must be computed through an iterative procedure using operating head, tailwater elevation, and turbine release. The initial turbine release is assumed to be that corresponding to maximum power production. Tailwater elevation at Hoover Dam is computed as a function of Lake Mohave elevation and Hoover Dam release.

The monthly Hoover Dam release volume at the base flow is computed by applying the base flow over the month. The monthly release volume at the peak flow is computed as:

$$PeakFlowVolume = TurbineReleaseVolume - BaseFlowVolume$$

Next, the number of hours required for operation at base and peak flows are computed as:

$$PeakHours = \frac{PeakFlowVolume}{(PeakFlow - BaseFlow) * 3600}$$

$$BaseHours = \frac{SecondsInMonth}{3600} - PeakHours$$

where 3,600 is the amount of seconds per hour.

If the peak hours are greater than the length of the month, the peak hours' value is set equal to the length of the month, and the base hours value is set to zero. The peak and base hours are then multiplied by the powerplant capacity at each level and added together to obtain the total energy produced for the month. Power is computed as the energy divided by the length of the month in hours.

The algorithm described above allows power generation at elevations below approximately 950 feet, which is the minimum power pool at Lake Mead. According to the algorithm, power is generated as long as the minimum operating head of 305 feet is available, corresponding to an elevation of about 950 feet. Because there is no operating experience at these elevations, it is impossible to verify whether CRSS mimics the actual turbine performance at such low heads. It is, therefore, critical to interpret energy results from CRSS in a relative, comparative manner rather than as absolute quantities.

Power capacity is the power that could be generated if the flow is directed through the penstock turbine(s) with a given operating head. This is computed to distinguish between actual power production and the power that could be produced.

A.9.3 Davis Dam

The method that computes power and energy generation at Davis Dam uses an empirical relationship as a function of flow, operating head, plant efficiency, and user-specified power coefficients. This empirical relationship is estimated by Reclamation and was last updated in 2019

using January 2012–September 2018 historical data. Energy is computed using this empirical relationship as:

$$Energy\ (MWH) = \left(C_1 * \frac{62.4}{737.5} * Outflow\ (1000\ cfs) * HoursInMonth * \frac{OperatingHead\ (ft)}{1000} - C_2 \right) * eff * 1000$$

where:

62.4 = the unit weight of water in pounds per cubic foot

737.5 = foot-pounds per second per kilowatt

C_1 = representations of the efficiency of the powerplant, estimated to be 0.88 based on historical data; C_1 must be a static value through the entire simulation

C_2 = represents any energy consumed within the powerplant and is set to 0 because Reclamation does not have necessary data to determine C_2

eff = representations of the efficiency of the powerplant estimated to be 1.0 and can vary (by month and/or year)

This energy method is different from the method used in CRSS for the 2007 Final EIS; this is because the analysis of energy methods in RiverWare™ indicated the new method simulates historical energy generation better than the method previously used in CRSS. This new method does not currently estimate the power capacity at Davis Dam, which was computed by the method used for the 2007 Final EIS.

A.9.4 Parker Dam

The method that computes power and energy generation at Parker Dam is the same method used for Davis Dam, except C_1 is set to 1.0; C_2 is estimated to be 0; and eff varies by month, as shown in **Table A-24**. The monthly efficiency coefficients are based on an analysis of historical data from Power, Operations, and Maintenance reports (January 2000–April 2021).

Table A-24
Parker Dam Monthly Efficiency Coefficients

Month	Coefficient
January	0.8192
February	0.8583
March	0.8645
April	0.8732
May	0.8705
June	0.8703
July	0.8658
August	0.8631
September	0.8588

Month	Coefficient
October	0.8636
November	0.8369
December	0.7710

A.10 Reservoir Evaporation

Evaporation in CRSS is calculated for the reservoirs listed in **Table A-25** and represents either net or gross evaporation depending on the reservoir and basin. Net evaporation is defined as evaporation after accounting for pre-reservoir (salvage) evaporation, whereas gross evaporation represents total evaporation from the reservoir surface without adjustment for pre-reservoir conditions. Upper Basin reservoirs (excluding Lake Powell; see **Section A.10.2**) use net evaporation coefficients and therefore produce net evaporation volumes, while Lower Basin reservoirs use gross evaporation coefficients and, therefore, produce gross evaporation volumes. Evaporation is computed for all reservoirs explicitly modeled in CRSS except for Strawberry, Starvation, and Taylor Park reservoirs.

Two RiverWare™ evaporation methods are applied within CRSS: Monthly Evaporation and Periodic Net Evaporation. The Monthly Evaporation method is described in **Section A.10.1**, and the Periodic Net Evaporation method is described in **Section A.10.2**.

Table A-25 summarizes the selected evaporation method and evaporation type for each reservoir.

Table A-25
Selected Evaporation Method Specified in CRSS

Reservoir	Evaporation Type	Selected Evaporation Method
Fontenelle	Net	Monthly Evaporation
Flaming Gorge	Net	Monthly Evaporation
TMD Reservoir*	Net	Monthly Evaporation
Blue Mesa	Net	Monthly Evaporation
Morrow Point	Net	Monthly Evaporation
Crystal	Net	Monthly Evaporation
McPhee	Net	Monthly Evaporation
Navajo	Net	Monthly Evaporation
Powell	Net	Periodic Net Evaporation
Mead	Gross	Monthly Evaporation
Mohave	Gross	Monthly Evaporation
Havasu	Gross	Monthly Evaporation

*TMD (Trans-Mountain Diversion) Reservoir combines Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoirs.

A.10.1 Monthly Evaporation Method

In RiverWare™, the Monthly Evaporation method calculates monthly reservoir evaporation using reservoir surface area and reservoir-specific monthly evaporation coefficients, as shown below:

$$Evaporation = Evaporation\ Coefficient \times \left(\frac{Surface\ Area_t + Surface\ Area_{t-1}}{2}\right)$$

where:

Evaporation Coefficient = monthly evaporation coefficient in ft/month
Surface Area = average reservoir surface area calculated from the current end of month (t) and previous end of month ($t-1$) expressed in acres
Evaporation = monthly evaporation expressed in acre-ft/month

Monthly evaporation coefficients for reservoirs using the Monthly Evaporation method are provided in **Table A-26**.

Table A-26
Monthly Evaporation Coefficients for Reservoirs Using the Input Evaporation and Monthly Evaporation Methods

Month	Evaporation Coefficient (ft/month)										
	Fontenelle	Flaming Gorge	TMD Reservoir*	Blue Mesa	Morrow Point	Crystal	McPhee	Navajo	Mead	Mohave	Havasu
January	0.10	0.05	0.00	0.02	0.02	0.02	0.00	0.05	0.32	0.33	0.34
February	0.10	0.06	0.01	0.03	0.03	0.03	0.05	0.06	0.29	0.28	0.41
March	0.10	0.08	0.06	0.06	0.06	0.06	0.11	0.13	0.32	0.37	0.48
April	0.14	0.13	0.12	0.09	0.09	0.09	0.22	0.20	0.43	0.46	0.59
May	0.25	0.21	0.27	0.13	0.13	0.13	0.33	0.28	0.55	0.52	0.70
June	0.34	0.27	0.37	0.17	0.17	0.17	0.48	0.33	0.67	0.51	0.81
July	0.35	0.35	0.32	0.18	0.18	0.18	0.43	0.35	0.64	0.45	0.90
August	0.29	0.33	0.24	0.13	0.13	0.13	0.32	0.28	0.70	0.57	0.89
September	0.24	0.29	0.15	0.12	0.12	0.12	0.28	0.22	0.68	0.61	0.81
October	0.16	0.19	0.09	0.07	0.07	0.07	0.13	0.14	0.64	0.55	0.65
November	0.10	0.09	0.02	0.03	0.03	0.03	0.04	0.07	0.56	0.49	0.46
December	0.10	0.05	0.00	0.02	0.02	0.02	0.00	0.05	0.46	0.48	0.35

*TMD (Trans-Mountain Diversion) Reservoir combines Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoirs.

A.10.2 Periodic Net Evaporation Method

Lake Powell is the only reservoir in CRSS that uses the Periodic Net Evaporation method. Under this method, evaporation is calculated as the difference between gross evaporation and salvage evaporation:

$$Evaporation = Gross\ Evaporation - Salvage\ Evaporation$$

Gross evaporation represents the total evaporation from Lake Powell and is calculated using average monthly surface area and gross evaporation coefficients, consistent with the calculation presented in **Section A.10.1**. The gross evaporation coefficients used for Lake Powell differ from the net evaporation coefficients used for the other Upper Basin reservoirs under the Monthly Evaporation method, and therefore require an additional step to calculate net evaporation. Monthly gross evaporation coefficients for Lake Powell are provided in **Table A-27**.

Table A-27
Lake Powell Monthly Evaporation Related Coefficients

Month	Gross Evaporation Coefficient (ft/month)	River Evaporation Coefficient (ft/month)	Streamside Coefficient (ft/°F)	Terrace Coefficient (ft/°F)	Average Precipitation (ft/month)	Average Air Temperature (°F)
January	0.17	0.17	0.006	0.005	0.06	37
February	0.18	0.18	0.006	0.005	0.05	42
March	0.27	0.27	0.008	0.006	0.05	50
April	0.38	0.38	0.008	0.007	0.03	59
May	0.44	0.44	0.009	0.007	0.03	69
June	0.63	0.63	0.009	0.007	0.02	80
July	0.77	0.77	0.009	0.008	0.04	86
August	0.77	0.77	0.009	0.007	0.05	83
September	0.72	0.72	0.008	0.007	0.06	74
October	0.53	0.53	0.007	0.006	0.08	61
November	0.49	0.49	0.006	0.006	0.06	47
December	0.38	0.38	0.006	0.005	0.04	37

Salvage evaporation is the evaporation that would have occurred within the reservoir inundation area under pre-reservoir conditions. The salvage evaporation calculation includes the sum of river evaporation, streamside evaporation, terrace evaporation, and a precipitation-related adjustment (remaining evaporation) used to estimate conditions that would have existed prior to the construction of Glen Canyon Dam. **Table A-27** includes the coefficients referenced in the following equations for the different components of salvage evaporation.

$$Salvage\ Evaporation = River\ Evaporation + Terrace\ Evaporation + Remaining\ Evaporation$$

$$River\ Evaporation = River\ Evaporation\ Coefficient \times \left(\frac{River\ Area_t + River\ Area_{t-1}}{2}\right)$$

$$Streamside\ Evaporation = Streamside\ Coefficient \times \left(\frac{Streamside\ Area_t + Stramside\ Area_{t-1}}{2}\right) \times Average\ Air\ Temperature$$

$$Terrace\ Evaporation = Terrace\ Coefficient \times \left(\frac{Terrace\ Area_t + Terrace\ Area_{t-1}}{2}\right) \times Average\ Air\ Temperature$$

$$Remaining\ Evaporation = Average\ Precipitation \times Remaining\ Area$$

$$Remaining\ Area = \left(\frac{Surface\ Area_t + Surface\ Area_{t-1}}{2}\right) - \left(\frac{River\ Area_t + River\ Area_{t-1}}{2}\right) - \left(\frac{Streamside\ Area_t + Stramside\ Area_{t-1}}{2}\right) - \left(\frac{Terrace\ Area_t + Terrace\ Area_{t-1}}{2}\right)$$

The river area, streamside area, and terrace area are all looked up using the specified month's elevation and a table that relates elevation to the specific area.

A.11 Salinity Method

The salinity module within CRSS is designed for long-term simulation over a horizon of 15 years and beyond and is the same for all alternatives. Results are particularly sensitive to initial conditions during the first 10 to 12 years. The method treats salinity as a conservative water quality parameter, and reservoirs are represented as fully mixed systems. Inputs include salinity associated with hydrologic inflows, initial reservoir salinity concentrations, estimates of salt loading from agricultural return flows, and salt removed by salinity control projects or trans-basin exports out of the basin[23]. Using these inputs, the CRSS produces annual average salinity concentrations at key numeric criteria stations located below Hoover Dam, below Parker Dam, and at Imperial Dam and at 17 locations above Hoover Dam. Salinity concentrations at Hoover Dam and above are computed using RiverWare™ model's water quality module, while concentrations at Parker Dam, Imperial Dam, and at the Northerly International Boundary (NIB) with Mexico are based on the calculations described below.

Salinity concentrations below Parker Dam and at Imperial Dam are projected as functions of concentrations below Hoover Dam using USGS-developed equations (Anning et al. 2018). Below Parker Dam, concentrations are estimated using a simple linear regression informed by Hoover Dam values, while concentrations at Imperial Dam are determined using a numerical model that incorporates tributary inflows and diversions. These equations were identified as the best available representation of downstream salinity concentrations relative to Hoover Dam concentrations.

The concentration below Parker Dam, C_{Parker} is calculated as:

$$C_{Parker} = 1.019 * C_{Hoover}$$

[23] The Yuma Desalting Plant is assumed to remain non-operational for the duration of the simulation.

The following equation and **Table A-28** are used to calculate concentration at Imperial Dam, $C_{Imperial}$:

$$C_{Imperial} = \frac{c_{12}c_{13}C_{Hoover}Q_{Main\ stem} + c_3C_{Parker}c_2Q_{Diversions} + c_6c_5(c_4 - Q_{Main\ stem}) + c_9c_8(P - c_7)}{c_1Q_{Main\ stem} + c_2Q_{Diversions} + c_5(c_4 - Q_{Main\ stem})} - c_{10}\frac{dc}{dt}$$

where:

$c_{1\text{-}13}$ = defined in **Table A-28**
C_{Hoover}, = salinity concentration at Hoover
C_{Parker} = 627 mg/L
$Q_{Main\ stem}$ = flow below parker minus Palo Verde Irrigation District and Colorado River Indian Reserve diversions
$Q_{Diversions}$ = sum of Palo Verde Irrigation District and Colorado River Indian Reserve diversions
dC/dt = change in Hoover salinity from the previous timestep

Table A-28
Estimated numerical model coefficients for the Parker Dam to Imperial Dam model and for the Hoover Dam to Imperial Dam model

Coefficient	Estimated value for the Parker Dam to Imperial Dam model	Estimated value for the Hoover Dam to Imperial Dam model	Units
c1	0.95	0.95	Dimensionless
c2	0.7	0.7	Dimensionless
c3	1.187	1.187	Dimensionless
c4	16,860	16,860	ft^3/s
c5	0.088	0.088	Dimensionless
c6	1,140	1,140	mg/L
c7	0	0	inches
c8	0	0	(ft^3/s)/inch
c9	0	0	mg/L
c10	0.5	0.55	Months
c11	5 through April 2008, and 0 thereafter	20 through April 2008, and 0 thereafter	mg/L
c12	NA	1.019	Dimensionless
c13[24]	NA	0.81	Dimensionless

Salinity concentration at the NIB is projected as a function of simulated salinity at Imperial Dam and base flows accruing to the river between Imperial Dam and the NIB. This logic does not simulate operations by Reclamation's Yuma Area Office to ensure compliance with the Minute No. 242 salinity differential. Rather, this logic assumes constant monthly base flows accruing to the Colorado River between Imperial Dam and the NIB to estimate the salinity at the NIB.

[24] If discharge from Bill Williams River is <1,000 ft^3/s, c_{13} = 1.0.

The salinity at the NIB is a function of the estimated volume of Colorado River water originating upstream from Imperial Dam, which is delivered to the NIB. This NIB volume is estimated as the total delivery to Mexico determined by CRSS, minus estimated deliveries to Mexico from sources downstream from Imperial Dam. These include deliveries from pumped groundwater and irrigation return flows to the Southerly International Boundary with Mexico; and pumped groundwater, base flow, irrigation return flows, and canal wasteway flows which accrue to the Colorado River between Imperial Dam and the NIB. Base flow and salinity concentration from these sources are represented between Imperial Dam and NIB as other measured flows, unmeasured flows, and pumped groundwater returned to the river. Flow and concentration values from these sources were estimated using available historical data from the period of 2018 through 2022. The salinity at the NIB is calculated via a simple monthly mass balance using the volume of Colorado River water delivered to Mexico through Imperial Dam (with the associated Imperial Dam salinity value) plus the base flows and their associated salinity values. These base flow values and salinity concentrations vary for each month but do not vary each year or across traces or alternatives.

Salinity concentration below Hoover Dam and at 17 locations represented in CRSS above Hoover Dam are determined with a basin-wide salinity modeling framework described in Prairie and Rajagopalan (2007), which is implemented within RiverWare™ model's water quality module. Natural flow and salt mass data for an observed period is first developed using Reclamation's RiverWare™ Natural Flow & Salt model (NFSM). Future salinity concentrations throughout the Colorado River watershed are generated using Reclamation's nonparametric natural salt model. This model relies on annual total flow–salt mass (Upper Basin) and intervening flow–salt mass (Lower Basin) regressions presently developed from 1991–2020 natural flow and salt mass data. The natural salt model provides salt mass estimates based on flows, from which salt concentrations are then calculated that align with natural hydrologic inflows input into CRSS. Present level agricultural salt loading is assumed to remain constant throughout the simulation period while projected increases in agricultural consumptive use are assigned a salinity pickup concentration that determines salt loading as a function of agricultural return flows. Variations in salt mass driven by extreme flow conditions are not explicitly represented; as a result, negative natural salt values can arise during computation.

To maintain realistic behavior at modeled stream gage locations, salt concentrations on river reaches are constrained within their historical minimum and maximum ranges, with any excess stored for later release when concentrations return to historical concentration ranges.

A.12 References

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Attachment A1

CRSS Lake Powell Assumed Monthly Releases

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Attachment A1. CRSS Lake Powell Assumed Monthly Releases

Table Attachment A1-1
CRSS Lake Powell Assumed Monthly Releases (Values in af)

Annual Total	October	November	December	January	February	March	April	May	June	July	August	September
5,000,000	403,000	397,000	425,000	438,000	392,000	429,000	406,000	416,000	412,000	436,000	444,000	402,000
6,000,000	410,000	430,000	510,000	570,000	500,000	530,000	470,000	470,000	500,000	560,000	600,000	450,000
7,000,000	480,000	500,000	600,000	664,000	587,000	620,000	552,000	550,000	577,000	652,000	696,000	522,000
7,480,000	480,000	500,000	600,000	723,000	639,000	675,000	601,000	599,000	628,000	709,000	758,000	568,000
8,230,000	643,000	642,000	715,000	763,000	675,000	713,000	635,000	632,000	663,000	749,000	800,000	600,000
9,000,000	643,000	642,000	715,000	857,000	758,000	801,000	713,000	710,000	745,000	842,000	900,000	674,000
9,500,000	643,000	642,000	715,000	919,000	813,000	858,000	764,000	761,000	798,000	902,000	963,000	722,000
10,000,000	643,000	642,000	715,000	980,000	870,000	920,000	810,000	810,000	850,000	960,000	1,030,000	770,000
10,500,000	643,000	642,000	715,000	1,041,000	921,000	973,000	866,000	862,000	905,000	1,022,000	1,091,000	819,000
11,000,000	643,000	642,000	715,000	1,102,000	975,000	1,030,000	917,000	913,000	958,000	1,082,000	1,156,000	867,000
11,500,000	643,000	642,000	715,000	1,160,000	1,030,000	1,090,000	970,000	960,000	1,010,000	1,140,000	1,220,000	920,000
12,000,000	643,000	642,000	715,000	1,225,000	1,083,000	1,145,000	1,020,000	1,014,000	1,064,000	1,202,000	1,284,000	963,000
12,500,000	643,000	642,000	715,000	1,290,000	1,140,000	1,200,000	1,070,000	1,060,000	1,120,000	1,260,000	1,350,000	1,010,000
13,000,000	643,000	642,000	715,000	1,347,000	1,192,000	1,259,000	1,121,000	1,116,000	1,171,000	1,322,000	1,413,000	1,059,000
13,500,000	643,000	642,000	715,000	1,410,000	1,250,000	1,320,000	1,170,000	1,170,000	1,220,000	1,380,000	1,480,000	1,100,000
14,000,000	643,000	642,000	715,000	1,470,000	1,300,000	1,373,000	1,223,000	1,217,000	1,277,000	1,443,000	1,537,000	1,160,000
14,500,000	643,000	642,000	715,000	1,530,000	1,350,000	1,430,000	1,270,000	1,270,000	1,330,000	1,500,000	1,600,000	1,220,000
15,000,000	643,000	642,000	715,000	1,590,000	1,410,000	1,490,000	1,320,000	1,320,000	1,380,000	1,560,000	1,670,000	1,260,000
15,500,000	650,000	650,000	750,000	1,650,000	1,450,000	1,540,000	1,370,000	1,370,000	1,420,000	1,620,000	1,730,000	1,300,000
16,000,000	650,000	650,000	800,000	1,720,000	1,490,000	1,590,000	1,410,000	1,420,000	1,480,000	1,670,000	1,780,000	1,340,000
16,500,000	650,000	650,000	800,000	1,770,000	1,550,000	1,650,000	1,470,000	1,460,000	1,530,000	1,730,000	1,850,000	1,390,000
17,000,000	650,000	650,000	800,000	1,840,000	1,600,000	1,700,000	1,510,000	1,510,000	1,590,000	1,790,000	1,920,000	1,440,000
17,500,000	650,000	650,000	800,000	1,900,000	1,650,000	1,760,000	1,560,000	1,570,000	1,640,000	1,850,000	1,980,000	1,490,000
18,000,000	650,000	650,000	800,000	1,960,000	1,710,000	1,820,000	1,620,000	1,620,000	1,690,000	1,910,000	2,040,000	1,530,000
20,000,000	800,000	800,000	1,000,000	2,000,000	1,760,000	1,880,000	1,980,000	2,040,000	1,980,000	2,040,000	2,040,000	1,680,000
30,000,000	1,600,000	1,600,000	1,900,000	2,500,000	1,900,000	2,500,000	2,500,000	2,800,000	3,100,000	3,400,000	3,400,000	2,800,000
50,000,000	2,666,667	2,666,667	3,166,667	4,166,667	3,166,667	4,166,667	4,166,667	4,666,667	5,166,667	5,666,667	5,666,667	4,666,667
75,000,000	4,000,000	4,000,000	4,750,000	6,250,000	4,750,000	6,250,000	6,250,000	7,000,000	7,750,000	8,500,000	8,500,000	7,000,000

Footnote:

Releases from 7.0 to 14.0 maf are from LTEMP; Monthly releases for the 5.0 maf annual volume are estimated for modeling purposes to maintain monthly releases above the LTEMP minimum daily volume. Releases outside this range are interpolated from LTEMP patterns for modeling purposes.

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Attachment A2

CRSS Lower Division States Water User Priorities

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Attachment A2. CRSS Lower Division State Water User Priorities

Water user names in the table reflect the water user names in the Colorado River Simulation System (CRSS) and will differ from the Shortage Allocation Model. There are several CRSS "water users" that aggregate multiple real-world users. In those cases, the assumed priority used in CRSS may not match the priority of all users; instead, the assumed priority is chosen as a modeling simplification. The shortage allocation model provides more detail on the distribution of shortages (see **Appendix C**).

Table Attachment A2-1
CRSS Input Lower Division State Water User Priorities

State	Water User	Priority
Arizona	LakeMeadMohaveNRA	2
	TVMarbleCanyonAZ	4
	McAlisterFamilyTrust	4
	FortMojaveIndResAZ	1
	MohaveValleyIDD	1
	MohaveValleyIDDAgPortion	4
	MohaveValleyIDDMandIPortion	4
	MohaveCoWASubcontract	4
	HavasuNWRAZ	2
	MohaveCountyWA	4
	MohaveWaterConsDist	4
	MohaveWaterConsDist-MohaveCoWASubcontract	4
	AzStateLandDeptMI	4
	AzStateParksWindsorBeach	4
	BullheadCity-MohaveCoWASubcontract	4
	BullheadCity	4
	BureauLandMgmt	4
	CrystalBeachWCD	4
	GoldenShoresWCD	4
	LakeHavasuCity-MohaveCoWASubcontract	4
	LakeHavasuCity	4
	UnallocatedPriority4	4
	SpringsDelSol	4
	GoldDomeMiningCo	4
	DavisDamProject	2
	CAPDiversion	4
	AkChinTribe	3

State	Water User	Priority
Arizona	SaltRiverTribe	3
	IndianWaterRightsSettlementsPriority4	4
	Parker	1
	EPCOR	1
	HopiTribe	4
	NorthBajaLLC	4
	GMGabrychFamily	4
	EPCOR	4
	EhrenbergImprDist	4
	FisherLanding	4
	HillcrestWaterCo	4
	Parker	4
	Quartzsite	4
	ShepardWaterCo	4
	FrontierCommWestCoast	4
	MartinezLakeSites	4
	BFInvestments	4
	LaPazCounty	4
	ImperialNWRAZ	2
	CibolaNWR	2
	CibolaValleyIDD	4
	AZGameAndFishCom	4
	GSCFarm	4
	RedRiverLandCo	4
	WesternWater	4
	BishopFamilyTrust	4
	Cathcarts	4
	CibolaSportsmansClub	4
	CRIRAZ	1
	NorthGilaValleyIDD	1
	YumaCountyWUA	1
	CityOfYuma	1
	UnitBIDD	1
	ArmyYumaProvingGround	3
	NavyMarineCorpsYumaAirStation	3
	UnivOfArizona	3
	YumaMesaFruitGrowersAssn	3
	YumaUnionHighSchool	3
	YumaCemetery	3
	CityOfYuma	3

State	Water User	Priority
Arizona	YumaIrrDist	3
	UnitBIDD	3
	YumaMesaIDD	3
	WelltonMohawkIDD	3
	KamanInc	3
	NorthGilaValleyIDD	3
	YumaCountyWUA	3
	CocopahIndRes	1
	GilaMonsterFarms	1
	Powers	1
	Molina	1
	GilaMonsterFarms	3
	DesertLawnMemorialPark	3
	AlecCamille	3
	HaroldSturges	3
	IrmaSturges	3
	UnionPacificCo	3
	GilaMonsterFarms	4
	DesertLawnMemorialPark	4
	CocopahIndRes	4
	FtYumaReservation	1
	PhillipsMiltonAndJean	1
	CurtisArmon	4
	ChaCha	4
	JRJPartners	4
	OgramBoysEnterprises	4
	OttFamily	4
	PhillipsMiltonAndJean	4
	BeattieFarmsSouthwest	4
	PasquinelliGaryAndBarbara	4
	EdwardRoy	4
	Somerton	4
	AzStateLandDeptAg	4
California	FortMojaveIndResCA	PPR
	CityOfNeedlesBernardinoCounty	PPR
	ChemehueviIndRes	PPR
	OthersAndMiscPresPerfRights	PPR
	QSAIIDtoMWDP3a	3(a)
	QSACVIDtoMWDP3a	3(a)
	MWDDiversion	4

State	Water User	Priority
California	CRIRCA	PPR
	PVIDDiversionPPR	PPR
	PVIDP1	1
	PVIDP3b	3(b)
	IIDDiversionPPR	PPR
	IIDDiversionP3a	3(a)
	QSAIIDtoCoachellaP3a	3(a)
	CoachellaDiversion3a	3(a)
	BardUnitPPR	PPR
	BardUnitP2	2
	QuechanResUnitA	PPR
Nevada	SNWPDiversion	8
	SNWPAdditionalDemand	8
	LaughlinAreaNevadaMI	8
	FortMojaveIndResNV	1 (PPR)
	NVDOW	7
	LakeMeadNRAP2	2
	LakeMeadNRAP1	1 (PPR)

Appendix B

Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
1944 Water Treaty	1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
af	acre-feet
AZ	Arizona
BICS	Binational Intentionally Created Surplus
Brock	Warren H. Brock Reservoir
BWSCP	Binational Water Scarcity Contingency Plan
CA	California
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CCS	Continued Current Strategies
cfs	cubic feet per second
CRIT	Colorado River Indian Tribes
CRSS	Colorado River Simulation System
CVWD	Coachella Valley Water District
DCP	2019 Drought Contingency Plan
DCP-ICS	Drought Contingency Plan Intentionally Created Surplus
EC-ICS	extraordinary conservation
EIS	environmental impact statement
GRIC	Gila River Indian Community
IBWC	International Boundary and Water Commission
ICS	Intentionally Created Surplus
IID	Imperial Irrigation District
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
maf	million acre-feet
Mexico	United Mexican States
MWD	Metropolitan Water District of Southern California

MWR	Mexico's Water Reserve
NWR	National Wildlife Refuge
Pub. L.	Public Law
Reclamation	Bureau of Reclamation
SNWA	Southern Nevada Water Authority
SRWYC	Sacramento River Water Year Classification
SRWYT	Sacramento River Water Year Type
U.S.	United States
YDP	Yuma Desalting Plant
Yuma County WUA	Water Users Association

Appendix B. Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water

B.1 Introduction

This appendix describes the Colorado River Simulation System (CRSS) modeling assumptions for the storage and delivery of conserved Colorado River system and non-system water in Lake Mead and Lake Powell pursuant to applicable federal Law, to increase flexibility in meeting water use needs while maintaining reservoir storage above critical elevations.

Extended drought, low reservoirs, and hydrologic variability from year to year create challenges when trying to plan for water supply and protect critical elevations. Conservation mechanisms that offer water users flexibility to conserve and/or augment water supplies can increase stability of the reservoirs, thereby reducing the need for and mitigating the impacts of large shortages. The alternatives represent a wide range of approaches to this element, ranging from no new conservation mechanism, to moderately sized pools in Lake Powell and Lake Mead open to users within the Upper and Lower Basins, respectively, to large, inclusive pools that may be flexibly stored in either reservoir to maximize their benefit to the system.

At this time, it is unknown which entities might participate in a Lake Mead or Lake Powell mechanism that allows the storage and delivery of conserved system and non-system water. Furthermore, the timing and magnitude of the storage and delivery of conserved water is unknown. These assumptions were developed to include the maximum amount of storage credits that may be created during any year, the maximum amount of storage credits that may be recovered during any year, and the maximum total amount of storage credits that may be available at any one time. Specific entities in CRSS had to be selected to model the storage and delivery mechanisms, including developing assumptions for their respective level of participation, to enable the evaluation of the mechanism and its potential effects on environmental resources. These assumptions are a reasonable and appropriate representation of potential conservation activities and the storage and delivery of water under the alternatives for purposes of environmental analyses, reflecting both the historical use of conservation programs and the need to bound the analysis by evaluating maximum potential impacts. The Bureau of Reclamation's (Reclamation) modeling assumptions are not intended to constitute a position on the use of the storage mechanisms by any specific water user nor are they an interpretation of the law, contracts or a legal position. Reclamation chose these modeling assumptions for a number of reasons, including the following: (1) a larger volume of potential storage in Lake Powell and Lake Mead is identified; (2) the maximum potential impacts on river flows downstream of Hoover Dam are identified; (3) concepts for the potential future use of a

storage mechanism are represented; and (4) the modeling impacts of a program of potential future cooperation between the United States (U.S.) and the United Mexican States (Mexico) are identified.

The following sections of this appendix discuss general modeling assumptions, then individual conservation creation, storage, and delivery assumptions for each alternative and the comparative baseline evaluated in this Final Environmental Impact Statement (EIS). These mechanisms may be in either Lake Powell, Lake Mead, or both reservoirs, and cover a range of possible conservation structures, maximum accumulations, and delivery rules.

B.2 General Modeling Assumptions

Three alternatives (Enhanced Coordination, Maximum Operational Flexibilities, and Supply Driven [both Lower Basin Priority (LB Priority) and Lower Basin Pro Rata (LB Pro Rata) approaches]) include assumptions for new storage and delivery mechanisms for conserved water in Lake Powell and Lake Mead. The Continued Current Strategies (CCS) Comparative Baseline assumes that existing agreements, including the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), 2017 Minute 323, and 2019 Drought Contingency Plan (DCP) continue through the analysis period (2027-2060), which includes an assumed continuation of the storage and delivery mechanism in Lake Mead. The No Action and Basic Coordination Alternatives only include assumptions for the delivery of Intentionally Created Surplus (ICS) created and stored before January 1, 2027.

The following sections explain the general modeling assumptions for the Lake Powell and Lake Mead mechanisms regarding how storage credits are generated and delivered within the CRSS model. Examples of the accounting of storage credits within the model are also presented below.

B.2.1 Lake Powell Mechanism

When storage credits are created, the conserved water is modeled by injecting as a lumped volume above Lake Powell on a water year basis. As such, the Lake Powell mechanism does not account for state or water-user specific balances. It is assumed that all water users in the Upper Basin, including tribal and non-tribal entities, would be able to contribute to the conservation pool; no assumptions are made with respect to where contributions of conserved water are generated or what specific activities generated the water for the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. The Enhanced Coordination Alternative includes an assumption that in addition to conservation, a portion of the Upper Basin Tribes' unused water could be contributed to the Lake Powell storage mechanism (see **Section B.6**).

The model assumes that the accounting of storage credits occurs annually, at the end of the water year. The initial balance (January 1, 2027) of the Lake Powell conservation mechanism is 0 acre-feet (af). Storage credits in Lake Powell are assumed to be subject to the following rules:

- If the Lake Powell conservation pool reaches full capacity, annual conservation continues; however, the conserved volumes are assumed to be system water rather than being stored in the Lake Powell storage mechanism.
- If Lake Powell releases additional water to maintain safe operating capacity, Lake Powell storage credits are assumed to be released first. Except for the Maximum Operational Flexibility Alternative, the conservation pool is reduced by the volume equal to the safe operating capacity release. In the Maximum Operational Flexibility Alternative, it is assumed that the safe operating capacity release moves water from the pool in Lake Powell to the pool in Lake Mead (see **Section B.7** for more information). Safe operating capacity releases are calculated as the difference between the actual water year release and the annual target release, adjusted for applicable releases constraints.
- At low lake levels, the storage credits in Lake Powell may exceed the total available storage.

B.2.2 Lake Mead Mechanism

B.2.2.1 Pre-2027 ICS, Mexico's Water Reserve, Mexico's Recoverable Water Savings, and Interstate Banking Initial Balances

The Interim Guidelines incorporate a conservation mechanism called ICS. The ICS mechanism has been in place since the 2007 Interim Guidelines operations were implemented. Each alternative, except the CCS Comparative Baseline, assumes the 2007 Interim Guidelines expire at the end of December 2026, and have their own assumptions on how to handle storage credits in Lake Mead at the end of 2026.

In addition to ICS conservation, Nevada has water stored in Arizona and California stored via the Interstate Water Banking mechanism. Agreements on the storage and withdrawal of this water are independent of ICS and any new conservation mechanism, and interstate banked water may be delivered through 2057. It is modeled as a delivery to Nevada from Lake Mead with a subsequent decrease in delivery from the state in which the water was pulled from. Interstate banking is assumed to be available in all alternatives and assumed to continue through 2060 as a source of conserved water Nevada can use. The interstate banked water is included in these assumptions as it is one source of water Nevada can use, and as such it is a component of the assumed delivery logic for Nevada.

Initial balances for all ICS types, as well as Mexico's Water Reserve (MWR), Mexico's Recoverable Water Savings, created as a contribution to Mexico's Binational Water Scarcity Contingency Plan (BWSCP), and Nevada's interstate banked water are included in **Table B-1**. **Table B-1** provides the end of calendar year 2026 balances as simulated by the November 2024 Colorado River Midterm Modeling System simulated with Ensemble Streamflow Prediction forecasts. The end of calendar year 2026 volumes were used to initialize conservation balances in all alternatives and are the same for all three sets of initial conditions.

Table B-1
Initial Balances (af)

State/Country - Water User - ICS Type	End of calendar year 2026
Arizona	
Central Arizona Water Conservation District (CAWCD)	
Binational ICS (BICS)	51,024
Extraordinary Conservation ICS (EC-ICS)	165,539
DCP-ICS	87,720
System Efficiency – Warren H. Brock (Brock)	100,000
System Efficiency – Yuma Desalting Plant (YDP) Pilot Run	3,050
Colorado River Indian Tribe (CRIT-AZ)	
CRIT EC-ICS	9,009
Gila River Indian Community (GRIC)	
GRIC EC-ICS	286,708
Total of EC-ICS, BICS, and DCP-ICS	**600,000**
California	
Imperial Irrigation District (IID)	
BICS	51,025
EC-ICS	50,000
The Metropolitan Water District of Southern California (MWD)	
BICS	51,024
EC-ICS	1,497,951
DCP-ICS	-
System Efficiency – Brock	65,000
System Efficiency – YDP	24,397
Total of EC-ICS, BICS, and DCP-ICS	**1,650,000**
Nevada	
Southern Nevada Water Authority (SNWA)	
BICS	51,024
EC-ICS	398,976
DCP-ICS	-
System Efficiency – Brock	400,000
System Efficiency – YDP	3,050
Tributary Conservation[1]	-
Nevada-Arizona Interstate Bank[2]	613,846
Nevada-California Interstate Bank[3]	330,225
Total of EC-ICS, BICS, and DCP-ICS	**450,000**

State/Country - Water User - ICS Type	End of calendar year 2026
Mexico	
Mexico's Recoverable Water Savings	175,500
MWR	150,000
Total of Mexico's Recoverable Water Savings + MWR	**325,500**

[1] The modeled tributary conservation initial balance is zero because it is assumed that any remaining Tributary Conservation at the end of the year is converted and stored as EC-ICS, subject to maximum accumulation limits.
[2] Water stored in Arizona by the Arizona WBA for the benefit of SNWA, Nevada. Not a type of ICS; listed in this table as it is a component of the assumed delivery logic for Nevada in CRSS.
[3] Water stored in California by the MWD for the benefit of SNWA, Nevada. Not a type of ICS; listed in this table as it is a component of the assumed delivery logic for Nevada in CRSS.

B.2.2.2 Generation of Storage Credits

When storage credits are created, the model assumes either a delivery from Lake Mead is decreased or a new gain to the system is introduced, resulting in an increase to Lake Mead storage. If the reduced delivery is located downstream of Lake Mead, creation of the storage credit results in a reduction in the release from Lake Mead and river flow downstream.

At the beginning of each year, the model assumes that storage credits will be generated based on model logic that varies by state/water user and alternative; the amount does not change throughout the year unless Lake Mead declines below critical elevations. The ability to generate storage credits varies by alternative; for alternatives with an assumed new storage mechanism, conservation credits in Lake Mead are assumed to be generated for the entire model simulation period of 2027 to 2060.

A one-time system assessment is assumed to be dedicated to the system upon the creation of storage credits. The system assessment varies among alternatives and is described in the subsequent alternative specific sections. For example, if an entity wishes to receive credit for 100 thousand acre-feet (kaf), then the credits that must be generated become: 100 kaf / (1 - system assessment).

The model assumes that the accounting of storage credits occurs annually, at the end of the calendar year. For alternatives that include assumptions for a new storage mechanism, storage credits in Lake Mead are assumed to be subject to the following rules:

- Storage credits in the Lake Mead mechanism can be created under Surplus, Normal, and Shortage Conditions
- The amount of storage credits that may be generated in a single year is constrained by assumed maximum annual and maximum total limits. If maximum limits are reached, volumes are proportionally reduced until the limit is reached. These assumed limits vary by alternative and are presented in the *General Assumptions* section for each alternative.

- If Lake Mead is at or near dead pool, creation of storage credits is cancelled for the remainder of the year, except the following:
  - Nevada's Tributary Conservation – the full volume of tributary conservation still occurs and is stored or delivered to Southern Nevada Water Authority (SNWA).
- Specific to the CCS Comparative Baseline, DCP-ICS creation and Mexico's Recoverable Water Savings creation is assumed to continue, if occurring.

B.2.2.3 Delivery of Storage Credits

All alternatives include assumptions for the delivery of existing, pre-2027 storage credits and alternatives that include assumptions for a new storage mechanism. When storage credits are delivered from Lake Mead, the model assumes that the delivery from Lake Mead was increased for that year, resulting in a decrease in Lake Mead storage. If the increased delivery is located downstream of Lake Mead, delivery of the storage credits results in an increase in the release from Lake Mead and downstream river flows. To mitigate shortage, a user may take delivery of storage credits or convert storage credits into system water (i.e., the volume of water delivered to the user is the same in either case). If Lake Mead is experiencing dead pool-related reductions, the delivery of storage credits is canceled for the remainder of the year. If Lake Mead is operating in flood control, any spill is first attributed to storage credits in the Lake Mead mechanism. For the CCS Comparative Baseline, the No Action Alternative and the Basic Coordination Alternative, all ICS balances are set to zero. For the Enhanced Coordination Alternative, the Maximum Operational Flexibility Alternatives, and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), individual water-user storage credits are reduced proportionally.

B.3 Continued Current Strategies Comparative Baseline

The CCS Comparative Baseline assumes that existing agreements, including the 2007 Interim Guidelines, 2017 Minute 323, and 2019 DCP continue through the analysis period (2027-2060). As part of this assumption, all types of ICS, MWR, and Mexico's Recoverable Water Savings are assumed to continue (creation and delivery) through the end of the analysis period.

B.3.1 Lake Powell Mechanism

No Lake Powell mechanism is modeled in the CCS Comparative Baseline.

B.3.2 Lake Mead Mechanism (ICS)

Storage credits can be delivered for objectives such as tribal firming obligations, augmenting water supplies during dry years, satisfy demands exceeding apportionment, or to satisfy DCP contributions (domestic water users) and BWSCP savings (Mexico) (see **Appendix A**, CRSS Model Documentation).

B.3.2.1 Treatment of Pre-2027 ICS

Pre-2027 ICS remains in their current ICS accounts and is immediately available for use, subject to existing rules, constraints, and assumptions.

B.3.2.2 General Assumptions

The maximum capacity of the ICS mechanism is 4.2 million acre-feet (maf), split between the Lower Division States and Mexico per the existing agreements. Each state/country has its own capacity and delivery limits, shown in **Table B-2**. Water users within a state may have agreed upon accumulation limits and/or modeling assumptions for the split of the state's accumulation limit, however, no creation or delivery limit exists for individual water users. For individual water user creation and delivery assumptions, see **Sections B.3.2.3 – B.3.2.6**.

Table B-2
Accumulation, Creation, and Delivery Limits by Entity in the Continued Current Strategies Comparative Baseline

State/Country	Arizona			California			Nevada	Mexico
Entity	CAWCD	Tribal	Total	IID	MWD	Total	Total	Total
Capacity (kaf)	250	250	**500**	50	1,650	**1,700**	**500**	**1,500**
Creation Limit (kaf)	-	-	**100**	-	-	**400**	**125**	**250**
Delivery Limit (kaf)	-	-	**300**	-	-	**400**	**300**	**200**

Assumptions for the creation and delivery of stored ICS water are designed to reflect the historical range of use of the ICS mechanism. ICS may be created through various mechanisms, including extraordinary conservation (EC-ICS), DCP contributions (DCP-ICS), Binational ICS (BICS), Tributary Conservation, system efficiency projects, and importation of non-Colorado River Water. Mexico has its own mechanism which can create conservation via MWR and Mexico's Recoverable Water Savings mechanism created as a contribution to Mexico's BWSCP. The following assumptions exist for the creation and delivery of the different ICS types, and are as follows:

- **EC-ICS/MWR**: Creation can occur at any pool elevation at Lake Mead. Delivery can occur when Lake Mead's pool elevation is above 1,025 feet at the start of the calendar year for all water users who are signatories to the DCP, while water users who are not signatories to the DCP can take delivery when Lake Mead's pool elevation is above 1,075 feet at the start of the calendar year.
- **DCP-ICS/BWSCP:** DCP-ICS can be created to satisfy required DCP contributions. It can be created by either (1) converting existing EC-ICS or (2) creating new EC-ICS and immediately converting to DCP-ICS. Delivery can occur when Lake Mead's pool elevation is greater than 1,110 feet at the start of the calendar year. The same assumptions are applied to Mexico's BWSCP contributions.
- **BICS:** BICS is credited to water users pursuant to agreements executed under Minutes 319 and 323. It is assumed that it can be delivered when Lake Mead's pool elevation is above 1,025 feet.
- **Tributary Conservation:** Creation from conservation on the Virgin and Muddy Rivers. Occurs annually and is converted and stored as EC-ICS if not used in the year it is created.

- **System Efficiency:** System Efficiency ICS creation occurs due to the implementation of system efficiency projects, such as building the Warren H. Brock Reservoir (Brock), and pilot operation of the Yuma Desalting Plant (YDP). No new creation of system efficiency ICS is modeled. Delivery is modeled to occur when Lake Mead's pool elevation is above 1,025 feet. Deliveries of Brock ICS are further constrained with maximum annual delivery volumes by water user, with a maximum of 25 kaf and 40 kaf for the Metropolitan Water District of Southern California (MWD) and Nevada, respectively, and a maximum of 65 kaf minus current year MWD and Nevada Brock ICS deliveries for Central Arizona Water Conservation District (CAWCD).
- **Imported ICS:** No imported ICS is modeled.

Accumulated ICS stored in Lake Mead is included in all operational determinations. The individual entities, or water users, assumed to use the storage and delivery mechanism are:

Table B-3
Existing ICS Water Users in the Continued Current Strategies Comparative Baseline

Water User	State
CAWCD	Arizona
CRIT-AZ	Arizona
GRIC	Arizona
IID	California
MWD	California
SNWA	Nevada
Mexico	Mexico

For all water users except Imperial Irrigation District (IID), in the year that EC-ICS, DCP-ICS, and Tributary Conservation is created and stored, a one-time system assessment of 10 percent is applied. For IID, because they are not a signatory to the DCP, in the year that ICS is created and stored, a one-time system assessment of 5 percent is applied, and a 3 percent evaporation assessment is applied to the stored volume (excluding current year's ICS creation) in every subsequent year.

B.3.2.3 Arizona Creation and Delivery Assumptions

In general, Arizona's creation and delivery logic was developed in coordination with Arizona Department of Water Resources and Central Arizona Project (CAP). Arizona is assumed to create ICS to help meet DCP contributions and take delivery of ICS to meet state and federal tribal firming obligations, mitigate shortages, and to recover all ICS by the end of the simulation horizon in most simulations.

Creation

Arizona is assumed to create and simultaneously convert 100 kaf of EC-ICS to DCP-ICS to contribute towards Arizona's DCP contribution, when required. The remaining required DCP contribution is assumed to be met through system water. There is no assumed additional creation of EC-ICS for any Arizona users.

Delivery

Generally, CAWCD is assumed to take delivery of conserved water when Arizona is experiencing shortage to mitigate shortages and to meet state and federal tribal firming obligations. The delivery volume is dependent on shortage volume.

CAWCD is assumed to take delivery of their EC-ICS, BICS, Brock and YDP ICS during Shortage Conditions to mitigate shortages. ICS is assumed to be delivered from CAWCD's stored EC-ICS credits first, followed by BICS, Brock, then YDP. ICS credits of one type will be completely withdrawn before moving to the next ICS type. Delivery volumes are dependent on the shortage volume and are shown in **Table B-4** below.

EC-ICS in the Arizona accumulation space is also assumed to be delivered to assist with satisfying state and federal tribal firming obligations. It is assumed that, of the Gila River Indian Community's (GRIC's) EC-ICS, (**Table B-1**) 16 kaf is modeled to be delivered for Arizona's firming obligations, while 160,708 af is modeled to be delivered for federal tribal firming obligations. This water is modeled to be delivered when the Lower Basin is in shortage and Lake Mead's pool elevation is less than or equal to 1,050 feet and greater than 1,025 feet. The firming volumes will be delivered from GRIC EC-ICS consistent with applicable agreements until the applicable GRIC EC-ICS runs out, after which deliveries will be made from remaining GRIC EC-ICS. The assumed delivery volumes are shown in **Table B-4**.[1]

Table B-4
Summary of CAWCD Delivery Volume Assumptions in the Continued Current Strategies Comparative Baseline

Lake Mead Pool Elevation (feet)	Arizona Shortage (kaf)	CAWCD (kaf)	GRIC EC-ICS for Arizona Firming (kaf)	GRIC EC-ICS for Federal Firming (kaf)	GRIC EC-ICS
<1,075 to ≥ 1,050	320	60	0	0	0
<1,050 to ≥ 1,025	400	100	15	10	15

Note: The non-Arizona non-federal government GRIC EC-ICS is only delivered after Arizona and the Federal Government's portion of GRIC's EC-ICS has been fully depleted.

If Lake Mead begins the calendar year above pool elevation 1,110 feet and DCP-ICS exists, CAWCD is assumed to take delivery of DCP-ICS up to the maximum annual ICS delivery limit (300 kaf; **Table B-2**) to recover DCP-ICS as quickly as possible.

There is no assumed delivery of Colorado River Indian Tribes' (CRIT's) EC-ICS.

[1] Please see the Arizona Water Settlements Act, Public Law (Pub. L.) 108-451, 118 Stat. 3478 (Dec. 10, 2004), section 105, for a general description of the firming program. All firming deliveries in any given year would be made in accordance with applicable law. This appendix is not a legal interpretation of the firming program or of federal obligations. Actual firming deliveries may vary from the modeling approximations contained in this appendix, and Reclamation retains discretion to include legally-required tribal deliveries in this priority mechanism.

B.3.2.4 California Creation and Delivery Assumptions

The ICS mechanism is assumed to be used by MWD and IID in California. MWD's ICS creation and delivery is based on the Sacramento River Water Year Type (SRWYT), while IID strives to maintain maximum ICS accumulation.

Creation

IID is assumed to maintain their maximum accumulation limit of 50 kaf. Approximately 1.5 kaf of EC-ICS is created when Lake Mead's pool elevation is above 1,075 feet (normal, ICS surplus, and domestic surplus years). This creation volume is the volume required to offset the annual 3 percent evaporation assessment applied annually, thus keeping their ICS at its maximum accumulation limit. If IID's ICS balance goes to 0 due to flood control conditions, IID is assumed to create up to 25 kaf of EC-ICS annually until the maximum accumulation limit is achieved. The following formula is used to determine IID's total EC-ICS creation:

$$IID\ EC-ICS\ Creaion\ (kaf) = Minimum(CA\ ICS\ Creation\ Limit\ (kaf) - \text{MWD ICS Creation}\ (kaf), 25\ kaf)$$

MWD's EC-ICS creation volumes are based on the annual Sacramento River Water Year Classification (SRWYC) index,[2,3] and are shown in **Table B-5** below.

Table B-5
MWD EC-ICS Creation Volumes by SRWYC in the Continued Current Strategies Comparative Baseline

SRWYC	Creation (kaf)
Critical (C)	0
Dry (D)	50
Below Normal (BN)	275
Above Normal (AN)	400
Wet (W)	400

DCP contributions for California are assumed to be contributed by MWD (93 percent) and Coachella Valley Water District (CVWD) (7 percent). MWD's portion of the DCP contribution volume is assumed to be made by converting existing EC-ICS, if available. If existing EC-ICS is insufficient to meet required DCP contributions, MWD will create EC-ICS and convert it to DCP-ICS to satisfy their contributions. If MWD's EC-ICS creation as per **Table B-5** is less than MWD's required DCP contribution volume, then additional EC-ICS will need to be created and converted to DCP-ICS to fully satisfy MWD's DCP contribution. CVWD's portion of the DCP contribution volume is supplied as an EC-ICS creation that is added to MWD's EC-ICS accumulation and converted to DCP-ICS. If MWD's maximum accumulation limit has been reached and there is

[2] Obtained at https://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

[3] Historical SRWYC is resampled using the index sequential method for hydrologic traces developed from resampling the Natural Flow record. For paleo data, the index is created from the Sacramento Valley 4 river index volume as reconstructed in Meko et al. (2014). For all other hydrology sequences, annual SRWYC values are generated using a trained decision tree model that was developed from the historical relationship between intervening natural flows and observed SRWYC, applied year-by-year to each sequence.

insufficient EC-ICS to convert to meet the DCP contribution, system water will be created to satisfy the outstanding DCP contribution volume.

Delivery

IID is not assumed to take delivery of their BICS or EC-ICS.

MWD's delivery volumes are based on the SRWYC index and are shown in **Table B-6** below. ICS deliveries will first be satisfied from DCP-ICS (if allowed, i.e., Lake Mead above 1,110 feet), then from EC-ICS, BICS, Brock, and YDP, respectively. Deliveries will completely recover stored ICS from one ICS category before moving on to the next.

Table B-6
MWD EC-ICS Creation Volumes by SRWYC in the Continued Current Strategies Comparative Baseline

SRWYC	Creation (kaf)
C	150
D	0
BN	0
AN	0
W	0

Additional ICS deliveries will be made to offset deliveries reductions due to Nevada's withdrawal from the California portion of the Interstate Water Bank. See **Section B.3.2.5**, Nevada Creation and Delivery Assumptions below for further information.

B.3.2.5 Nevada Creation and Delivery Assumptions

In Nevada, ICS is assumed to be created and delivered by SNWA. SNWA is assumed to try to fully satisfy their annual depletion schedule plus any demands that exceed apportionment.

Creation

There are two ICS types with modeled creation by SNWA: EC-ICS and Tributary Conservation. SNWA is assumed to create EC-ICS from conserved water under SNWA's exhibit for EC-ICS as long as Nevada has not achieved their total accumulation limit (**Table B-2**).

SNWA's annual EC-ICS creation is calculated using the following equation:

$$Annual\ Creation = Maximum(\ 300{,}000\ af - \ Annual\ Shortage_{NV} - Annual\ Demand_{NV}, 0\ af)$$

Based on the assumed depletion schedules, SNWA attempts to create ICS until 2047, at which point demands equal full apportionment (see **Appendix M**, Lower Division States Depletion Schedules).

Tributary conservation occurs annually and represents conservation on the Virgin and Muddy Rivers, generating an assumed 35 kaf per year, which is converted to EC-ICS if not delivered in the year it is created. If Nevada is at their maximum total accumulation limit, or Lake Mead is

experiencing dead pool-related reductions, Tributary Conservation will still be created and will be delivered to SNWA the same year.

If there is a required DCP contribution, SNWA is assumed to convert EC-ICS to DCP-ICS to satisfy their DCP contribution. If there is not enough EC-ICS available to meet the full DCP contribution, SNWA will create additional EC-ICS and convert it to DCP-ICS to satisfy the DCP contribution. If Nevada has reached their maximum accumulation limit, SNWA will make the DCP contribution via system water.

Delivery
SNWA is assumed to take delivery of ICS and/or Interstate Banked Water to satisfy demands exceeding apportionment and/or offset Nevada's annual shortage and DCP contributions, and can be calculated using the following equation, subject to the maximum delivery constraint of 300 kaf (**Table B-2)**:

$$\textit{Annual Delivery} = \textit{Maximum}\left(\begin{matrix}\textit{Annual Depletion Schedule}_{NV} + \textit{Demands Exceeding Apportionment}_{NV} \\ -(300{,}000\ af - \textit{Annual Shortage}_{NV} - \textit{ECICS or System Water creation for DCP contribution}_{NV}), \\ 0\ af\end{matrix}\right)$$

The modeled demands do not exceed apportionment until 2047, after which they increase through 2060 as shown in **Table B-7**.

Table B-7
Nevada Demands Above Apportionment

Year	Demands Above Apportionment (af)
2027-2046	0
2047	2,339
2048	5,460
2049	8,554
2050	11,410
2051	14,447
2052	17,455
2053	20,433
2054	23,381
2055	26,310
2056	29,194
2057	32,047
2058	34,979
2059	37,764
2060	40,415

If available, surplus water is used first to meet the calculated annual delivery during surplus years. Then, different categories of ICS and Interstate Banked Water are used to meet the calculated annual delivery. Nevada is assumed to take delivery of ICS and Interstate Banked Water in the

following order, with one ICS category being completely exhausted or delivered to its annual delivery limit before progressing to the next:

1. DCP-ICS
2. Tributary Conservation
3. Brock ICS
4. YDP ICS
5. BICS
6. Nevada-Arizona Interstate Water Bank
7. Nevada-California Interstate Water Bank
8. EC-ICS

If Lake Mead starts the year with a pool elevation below 1,025 feet, EC-ICS, BICS, and System Efficiency ICS (Brock and YDP) are assumed to not be delivered; however, current year Tributary Conservation ICS and Interstate Water Bank deliveries can be made. In this case, the model would skip all EC-ICS, BICS, and System Efficiency ICS categories and try to satisfy the annual delivery from Tributary Conservation and Interstate Water Banking balances.

The Interstate Water Bank represents water stored in California and Arizona for the benefit of SNWA. Deliveries from the Interstate Water Bank are modeled by increasing SNWA's delivery and reducing CAP and/or MWD's delivery by the same volume, depending on whether it is a delivery from the Arizona or California Interstate Water Bank, respectively.

Deliveries from the Interstate Water Bank include assumed constraints on the maximum delivery that can be withdrawn from the bank each year. Specifically, in the first-year water from the Arizona bank is needed, SNWA can withdraw up to 20 kaf, followed by 30 kaf in the following consecutive year, and 40 kaf in the remaining consecutive years. Delivery from the Nevada-Arizona bank is further constrained if it is a shortage year. The maximum delivery from the Nevada-Arizona bank is reduced proportional to the reduction in CAP's municipal and industrial delivery due to shortages.

The maximum SNWA can withdraw from the Nevada-California Interstate Water Bank is assumed to 30 kaf per year. In years when SNWA withdraws from the Nevada-California bank, MWD first tries to offset their delivery reduction by taking delivery of their ICS. In years when MWD is unable to offset the bank delivery with ICS, their delivery is reduced by a like amount delivered to SNWA.

B.3.2.6 Mexico Creation and Delivery Assumptions[4]

Mexico is assumed to create and deliver MWR on a three-year cycle. Mexico is assumed to satisfy their BWSCP savings via creating Mexico's Recoverable Water Savings (BWSCP).

4 Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Creation
Mexico is assumed to create 60 kaf of MWR every three years starting in 2027.

Mexico is assumed to create Recoverable Water Savings to satisfy their BWSCP savings if Mexico has not reached their total accumulation limit (**Table B-2**). If no space is available, BWSCP savings are met as system water.

Delivery
Mexico is assumed to take delivery of up to 27 kaf in years that they are not creating MWR.

Mexico is assumed to take delivery of 25 kaf of Recoverable Water Savings when allowed, i.e., Lake Mead is above 1,110 feet.

The total annual delivery of MWR and Recoverable Water Savings is assumed to not exceed 27 kaf, with Recoverable Water Savings deliveries taking precedence over MWR deliveries.

B.4 No Action Alternative

The No Action Alternative assumes that there is no new conservation mechanism to proactively conserve and store water in Lake Powell or Lake Mead, therefore the existing conservation mechanism will operate as per the current agreements, which expire at the end of 2026. Water users have through the end of 2036 to remove all ICS types except DCP-ICS, which can be delivered through the end of 2057. All ICS remaining in Lake Mead after the respective expiration dates is assumed to become system water.

B.4.1 Lake Powell Mechanism
No Lake Powell mechanism is modeled in the No Action Alternative.

B.4.2 Lake Mead Mechanism
The No Action Alternative assumes that the ICS mechanism expires at the end of 2026, and water users may take delivery of existing ICS in accordance with the dates specified in the respective agreements, but no new creation and storage is allowed, with one exception described in the following sections. Water users can take delivery of EC-ICS and System Efficiency ICS through 2036 and DCP-ICS through 2057; if ICS storage credits remain in Lake Mead on January 1, 2037 (or 2057 for DCP-ICS), they are assumed to become system water. As a result, the No Action Alternative assumptions reflect water users' efforts to take delivery of ICS storage credits prior to this deadline.

Exceptions to this include Tributary Conservation ICS and Interstate Water Banking, which are assumed to continue through 2057.

B.4.2.1 Treatment of Pre-2027 ICS
Pre-2027 ICS is modeled based on the existing ICS types and respective rules for delivery beyond 2026.

B.4.2.2 General Assumptions

The No Action Alternative utilizes the same Lake Mead ICS mechanism as is described in **Section B.3**, Continued Current Strategies Comparative Baseline, with the additional assumption that Interim Guidelines ICS and 2019 DCP conservation agreements have expired, and the creation of EC-ICS, DCP-ICS, BICS and System Efficiency ICS may no longer occur after the end of calendar year 2026.

Tributary Conservation and Imported ICS can be created and delivered through the end of calendar year 2057, but cannot be stored, i.e., they are assumed to be created and delivered in the same year. Any creation of these ICS types is modeled to incur a 5 percent assessment upon creation. Because the 2019 DCP has expired, all ICS balances are assessed a 3 percent evaporation assessment.

For further modeling assumptions, please see **Section B.3.2.2**, General Assumptions from the CCS Comparative Baseline.

B.4.2.3 Arizona Delivery Assumptions

Arizona is assumed to try and take delivery of all conserved ICS water before it expires at the end of 2036 for EC-ICS, BICS, and System Efficiency ICS, and at the end of 2057 for DCP-ICS.

Delivery

CAWCD is modeled to take delivery of their remaining EC, Binational, Brock, and YDP ICS by 2036 by taking delivery of 150 kaf per year through 2029, then by taking delivery up to Arizona's maximum annual delivery of 300 kaf from 2030-2036, until all CAWCD ICS has been delivered. CAWCD's EC-ICS credits are delivered first, followed by BICS, Brock, then YDP.

CRIT is assumed to take delivery of all their EC-ICS the first year they are able to do so.

It is assumed that of GRIC's EC-ICS (**Table B-1**) 16 kaf is modeled to be delivered for Arizona's firming obligations, while 160,708 af is modeled to be delivered for federal tribal firming obligations. The firming volumes will be delivered from GRIC EC-ICS consistent with applicable agreements until the applicable GRIC EC-ICS runs out. The portion of GRIC's EC-ICS that is modeled for federal firming is assumed to be delivered during Shortage Conditions to meet federal firming obligations, with the modeled delivery volumes shown in **Table B-8**.[5] In 2036, if there is still GRIC EC-ICS for federal firming, the entire available volume is assumed to be delivered, if possible, based on other constraints.

[5] Please see the Arizona Water Settlements Act, Pub. L. 108-451, 118 Stat. 3478 (Dec. 10, 2004), section 105, for a general description of the firming program. All firming deliveries in any given year would be made in accordance with applicable law. This appendix is not a legal interpretation of the firming program or of federal obligations. Actual firming deliveries may vary from the modeling approximations contained in this appendix, and Reclamation retains discretion to include legally-required tribal deliveries in this priority mechanism.

Table B-8
GRIC EC-ICS for Federal Firming - Assumed ICS Delivery by Lake Mead Pool Elevation in the No Action Alternative

Pool Elevation	Delivery Volume (af)
<1,075 to ≥ 1,050	24,325
<1,050 to ≥ 1,025	36,924

15 kaf/year of the GRIC EC-ICS that is for Arizona firming is assumed to be delivered during Shortage Conditions when Lake Mead's pool elevation is less than 1,050 feet and greater than or equal to 1,025 feet until supplies are depleted.

GRIC is assumed to attempt to take delivery of their remaining EC-ICS that is not for Arizona or federal firming by 2036. The modeled annual delivery volume is computed as the GRIC EC-ICS balance divided by the number of years remaining through the end of 2036.

DCP-ICS is assumed to be recovered as fast as possible when Lake Mead's pool elevation is above 1,110 feet. (i.e., all existing DCP-ICS is recovered up to the maximum annual ICS delivery limit).

B.4.2.4 California Delivery Assumptions

The ICS mechanism is assumed to be used by MWD and IID in California as they are the users in California with existing ICS.

Delivery

IID is modeled to take delivery of as much of their EC-ICS as possible when Lake Mead's pool elevation is greater than 1,075 feet. MWD's ICS delivery is prioritized above IID's ICS delivery. IID's ICS delivery can be calculated using the equation:

$$IID\ ICS\ Delivery\ (kaf) = Maximum(CA\ ICS\ Delivery\ Limit\ (kaf) - \text{MWD ICS Delivery}\ (kaf), 0\ kaf)$$

MWD's ICS delivery volumes are based on the annual Sacramento River Water Year Classification (SRWYC) (see **Section B.3.2.4**, *California Creation and Delivery Assumptions*). ICS deliveries will first be satisfied from DCP-ICS (if allowed), then from EC-ICS, BICS, Brock, and YDP, respectively. Deliveries will completely recover ICS from one ICS type before moving on to the next. **Table B-9** below shows MWD's assumed delivery volume by SRWYC.

Table B-9
MWD ICS Assumed Delivery Volumes by SRWYC in the No Action Alternative

SRWYC	Delivery (af)
W	25,000
AN	25,000
BN	100,000
D	225,000
C	400,000

Additional ICS deliveries may also occur to offset delivery reductions due to Nevada's withdrawal from the California portion of the Interstate Water Bank. See **Section B.4.2.5**, *Nevada Creation and Delivery Assumptions* below for further information.

B.4.2.5 Nevada Creation and Delivery Assumptions

In Nevada, ICS is assumed to be created and delivered by SNWA. SNWA is assumed to try to fully satisfy their annual depletion schedule plus any demands that exceed apportionment.

Creation

At the start of 2027, SNWA is still able to create Tributary Conservation water, and is assumed to do so to a volume of 35 kaf per year until 2057 when the Tributary Conservation agreements expire. Based on the No Action Alternative assumption of no new storage and delivery mechanism, Tributary Conservation is no longer able to be converted to EC-ICS and stored in the Lake Mead ICS mechanism. A 5 percent assessment is applied to the Tributary Conservation ICS, and the remaining volume is delivered to SNWA.

Delivery

It is assumed that SNWA will attempt to recover their ICS that expires in 2036 using the following equation:

$$Full\ ICS\ Recovery_{year} = \frac{\sum Expiring\ ICS\ Type\ balances}{nYears\ until\ 2036 + 1}$$

where:

$\sum$*Expiring ICS Categories balances* = sum of balance of all ICS types that are set to expire at the end of 2036 (EC-ICS, BICS, Brock, YDP)

nYears until 2036 = number of years until 2036 including the current year; 1 is added because recovery can occur through the end of 2036

year = current year

"Full ICS Recovery" is modeled to be recovered in the following order, with one ICS category being completely recovered before progressing to the next:

1. Brock ICS
2. YDP ICS
3. BICS ICS
4. EC-ICS

Additional ICS can be used to satisfy Nevada's scheduled demand if the above computed delivery is not enough. This additional delivery is calculated as:

$$\begin{aligned} &Additional\ ICS\ Delivery \\ &\quad = Maximum(\ 300{,}000\ af - \ Annual\ Shortage_{NV} - Annual\ Depletion\ Schedule_{NV} \\ &\quad + \ Annual\ ICS\ Delivery_{Full\ ICS\ Recovery}, 0\ af) \end{aligned}$$

If an additional ICS delivery is required, ICS will be delivered from different categories of ICS in the order laid out in **Section B.3.2.5**, *Nevada Creation and Delivery Assumptions*, recovering one type either completely or to its annual delivery limit before progressing to the next.

Tributary conservation will be delivered in the same year as it was created.

After 2037, SNWA is assumed to take delivery of interstate bank water to satisfy demands exceeding apportionment or when Nevada's shortage reduces Nevada's use below their scheduled use by more than SNWA's annual tributary conservation, and is calculated using the following equation:

$$\begin{aligned} &Interstate\ Water\ Bank\ Requested\ Delivery \\ &= Maximum\begin{pmatrix} Annual\ Depletion\ Schedule_{NV} + \ Demands\ Exceeding\ Apportionment_{NV} \\ -(\ 300{,}000\ af - \ Annual\ Shortage_{NV}) - 35\ kaf_{Tributary\ Conservation} \\ 0\ af \end{pmatrix} \end{aligned}$$

Interstate banked water is recovered from the water stored in Arizona first, followed by the water stored in California. Assumed delivery limits for each Interstate Water Bank are the same as the limits in the CCS Comparative Baseline and can be found in **Section B.3.2.5**, *Nevada Creation and Delivery Assumptions*.

B.4.2.6 Mexico Delivery Assumptions[6]

Mexico is assumed to try and take delivery of all MWR and Recoverable Water Savings through the end of 2060.

Delivery

Mexico is assumed to take delivery of 25 kaf of MWR water in years where Lake Mead's pool elevation is greater than 1,075 feet at the start of the calendar year. MWR deliveries are assumed to be able to occur through the end of 2060.

Mexico is assumed to take delivery of 25 kaf of its Recoverable Water Savings when Lake Mead's pool elevation is above 1,110 feet at the start of the calendar year. Recoverable Water Savings are assumed to be able to be delivered through the end of 2057.

6 Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In years when the delivery of both MWR and Recoverable Water Savings is possible, the total delivery is assumed to be constrained to a maximum of 25 kaf and priority will be given to the delivery of Recoverable Water Savings.

B.5 Basic Coordination Alternative

The Basic Coordination Alternative assumes that there is no new conservation mechanism to proactively conserve and store water in Lake Powell or Lake Mead, therefore the existing conservation mechanism will operate as per the current agreements, which expire at the end of 2026. Water users have through the end of 2036 to remove all ICS types except DCP-ICS, which can be delivered through the end of 2057. All ICS remaining in Lake Mead after the respective expiration dates is assumed to become system water.

The Basic Coordination Alternative uses the same conservation logic as the No Action Alternative. For details on the modeling assumptions, refer to **Section B.4**, No Action Alternative.

B.6 Enhanced Coordination Alternative

The Enhanced Coordination Alternative includes three pools to store, convert and deliver water for the benefit of water users and the system: the Lake Powell mechanism, the water user-controlled Lake Mead mechanism, and the Lake Mead Protection Pool, which was informed by a group of Basin Tribes and would be controlled by Reclamation for Lower Basin-wide benefits. The design of these mechanisms supports proactive conservation and water user flexibility while the relatively lower accumulation limits represent a goal of ensuring that system storage is not overtaken by user-controlled conservation.

Details on modeling assumptions for each mechanism including creation, delivery, and associated constraints are provided below.

B.6.1 Lake Powell Mechanism

As described in **Appendix S,** water conserved by Upper Basin users would be stored in a pool in Lake Powell that can reach a maximum volume of 2.0 maf. Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool and to use their conserved water in intra- and interstate transactions with other Upper Basin users; however, no modeling assumptions were developed to model those specific transactions in the Enhanced Coordination Alternative. Additionally, water held in the Lake Powell conservation pool would be converted to system water and combined with Lower Basin shortages to provide system benefits based on the shortages specified in the Enhanced Coordination Alternative; assumptions regarding this conversion are detailed below.

B.6.1.1 General Assumptions

The volume of water in the Lake Powell conservation pool affects the determination of Lake Powell's water year release, as the calculation for the release accounts for the physical storage in

Lake Powell and Lake Mead, but it does not affect the Lower Basin/Lake Mead operations as they are determined using a combination of the effective storage[7] at Lake Powell coupled with the physical storage at Lake Mead. There is a maximum capacity of 2.0 maf. There are no assumed state-specific limitations on the maximum accumulation, nor are there state-specific annual creation and delivery limits, as conservation creation for the Lake Powell mechanism is modeled as a total Upper Basin volume.

There is an annual deduction for evaporation equal to the conservation pool's proportional share of total evaporation from Lake Powell. The evaporation deduction is applied annually in October based on the previous year's evaporation computed using the RiverWare™ Periodic Net Evaporation method and the total volume in the conservation pool at the end of the previous water year. Additionally, it is assumed a one-time system assessment of 7 percent is applied in the year the water is conserved and stored.

B.6.1.2 Creation

Storage credits are assumed to be created and stored in the Lake Powell conservation pool in two different ways: Upper Basin conservation and storage of a portion of unused Upper Basin tribal water. While the conservation is modeled as a single lumped gain to Lake Powell and no assumptions are made with respect to contributions from different entities, or via specific activities, it is contemplated that both the Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool.

For modeling purposes, unused Upper Basin tribal water is calculated as the difference between each tribe's depletion entitlement (or depletion equivalent) and its corresponding annual baseline depletion demand. Between 5 to 15 percent of the unused Upper Basin tribal water is assumed to be available for storage in the Lake Powell mechanism. The specific percentage, which varies with hydrologic conditions, is determined by comparing the modeled water year Lees Ferry natural flow to the 1991–2020 historical average (**Table B-10**). Linear interpolation is used to determine the specific percentage when the modeled (water year) Lees Ferry natural flow falls between 13.49 and 20.24 maf—with contributions increasing proportionally from 5 percent to 15 percent as natural flow increases across this range. The volume computed based on this relationship is assumed to be stored in the Lake Powell pool, without changing the inflow to Lake Powell.

Appendix H, Sensitivity Analysis - Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative, provides information on the methodology used to estimate the Upper Basin unused tribal water, which was needed to model this concept and documents other relevant assumptions and caveats related to these assumptions.

[7] "Effective" elevation or storage is calculated as physical elevation (storage) minus any conserved volume that is held in the respective reservoir(s).

Table B-10
Upper Basin Tribal Water Available for Storage in the Lake Powell Conservation Pool (Enhanced Coordination Alternative) Relative to Historical Lees Ferry Natural Flow Thresholds

Current Water Year Lees Ferry Natural Flow (maf)	Annual Upper Basin Unused Tribal Contribution (%)
≥ 20.24[8]	15
Between 20.24 and 13.49[9]	5 to 15 (linear interpolation)
= 13.49	5
< 13.49	0

Exact volumes of Upper Basin conservation over time are uncertain, but for modeling purposes, conservation volumes up to a specified annual maximum may be added in any given year, depending on hydrologic conditions. The modeled conservation volume is determined by comparing the modeled water year Lees Ferry natural flow to the historical 1991–2020 25th and 75th percentile thresholds shown in **Table B-11**. Linear interpolation is used when the modeled Lees Ferry natural flow falls between 10.6 and 16.5 maf—with conservation increasing from 0 to the maximum volume as natural flow increases across this range.

Table B-11
Upper Basin Modeled Annual Conservation Volumes in the Enhanced Coordination Alternative

Current Water Year Lees Ferry Natural Flow (maf)	Annual (Water Year) Upper Basin Conservation (kaf)		
	2027-2031	2032-2036	2037-2060
> 16.50[10]	200	275	350
Between 16.50 and 10.60[11]	200 to 0 (linear interpolation)	275 to 0 (linear interpolation)	350 to 0 (linear interpolation)
≤ 10.60	0	0	0

Annual conservation volumes are disaggregated to the monthly scale using the average monthly Upper Basin agricultural demand distribution shown in **Table B-12**. These monthly volumes are then modeled as an inflow above Lake Powell.

[8] 150 percent of the historical average Lees Ferry natural flow from 1991-2020.
[9] Historical average Lees Ferry natural flow from 1991-2020.
[10] Historical 1991–2020 75th percentile Lees Ferry natural flow value.
[11] Historical 1991–2020 25th percentile Lees Ferry natural flow value.

Table B-12
Average Monthly Upper Basin Agricultural Demand Distribution

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Percent	0%	0%	1%	4%	15%	25%	27%	17%	8%	3%	0%	0%	100%

B.6.1.3 Delivery/Conversion

Storage credits in the Lake Powell conservation pool are assumed to be converted to system water and combined with Lower Basin shortages to provide system benefits based on the shortage. When Lower Basin calendar year shortages are greater than 1.5 maf, a volume equal to one-third of the volume above 1.5 maf would be converted from the Lake Powell pool into system water such that the total of Lower Basin shortages and conversion of Upper Basin water equals the required total shortage volume (i.e., above 1.5 maf, there is a 2-to-1 Lower Basin shortage-to-Upper Basin conversion ratio). If the prescribed 2-to-1 volume is not available in the Lake Powell conservation pool, 100 percent of the available volume would be converted, and the Lower Basin would take the balance of shortages.

Water created for storage in the Lake Powell mechanism is not available for conversion in the year in which it is created.

B.6.2 Lake Mead Mechanism

As described in **Appendix S**, this pool represents the water user-controlled Lake Mead mechanism. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users. Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 5.0 maf, which includes the storage of pre-2027 ICS. Water users could contribute and convert or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool. All conserved storage credits in Lake Mead would be included in determinations of Lake Powell releases and shortage volumes.

The subsequent sections provide a detailed description of the modeling assumptions and associated constraints.

B.6.2.1 Treatment of Pre-2027 ICS

For modeling purposes only, ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 is converted to the Post-2026 Lake Mead water user-controlled mechanism on January 1, 2027.[12]

B.6.2.2 General Assumptions

The maximum capacity of the Lake Mead mechanism, along with individual annual creation and delivery limits, is provided in **Table B-13** below. The Lake Mead mechanism operates on a calendar

[12] The modeling erroneously excludes the conversion of system efficiency ICS to the Lake Mead mechanism.

year to align with reservoir operations. Delivery/conversion from the Lake Mead mechanism is prohibited if Lake Mead starts the year with a physical pool elevation below 1,025 feet.[13]

Table B-13
Lake Mead Mechanism Limitations of Storage of Conserved Water in the Enhanced Coordination Alternative

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery (kaf)
Arizona	466.667	700	620
California	733.333	1,900	980
Nevada	50	700	70
Mexico[1]	250	1,700	330[2]
Total	**1,500**	**5,000**	**2,000**

1) Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty) or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission (IBWC) in consultation with the Department of State.

2) According to the modeling assumption for Mexico, storage credits in the bank may only be used to mitigate Mexico's reductions exceeding 250 kaf. This activity is considered a "delivery" (i.e., conversion) from the bank. As a result, banking activity will not cause Mexico's delivery to exceed 1.7 maf. The 1944 Water Treaty authorizes scheduled delivery of up to 200 kaf in excess of the 1.5 maf annual allotment to Mexico.

The conservation activity is modeled using the following water users:

Table B-14
Lake Mead Mechanism Water Users in the Enhanced Coordination Alternative

Water User	Entity
CAP	Arizona
Colorado River Indian Tribe (CRIT-AZ)	Arizona
MWD	California
IID	California
Colorado River Indian Tribe (CRIT-CA)	California
SNWA	Nevada
Mexico	Mexico

It is assumed that a one-time system assessment of 7 percent is applied in the year the water is conserved and stored. This volume of water is assumed to be stored in the Protection Pool as "System Assessment" storage credits, subject to the Protection Pool's constraints and associated modeling assumptions (**See Section B.6.3.3**, *System Assessment Creation*). Additionally, there is an

[13] The logic included in CRSS erroneously did not apply this constraint to the delivery/conversion of California's storage credits.

annual deduction for evaporation equal to the conservation pool's proportional share of total evaporation from Lake Mead. The evaporation deduction is applied annually in January based on the previous year's evaporation computed using the RiverWare™ Input Evaporation method and the total volume in the conservation pool at the end of the previous calendar year.

B.6.2.3 Arizona Creation and Conversion/Delivery Assumptions

In general, Arizona's creation and delivery of conserved water is inversely related to the combined storage of Lake Mead (physical) and Lake Powell (effective) and the state shortage volume.

For modeling purposes, Arizona's conservation activity is modeled using CAP and CRIT-Arizona (AZ).

Creation

Arizona can create up to 466.667 kaf per year, depending on the state's total shortage volume. An overview of the logic is provided below, followed by a summary in **Table B-15**.

- If the combined storage of Lake Mead (physical) and Lake Powell (effective) exceeds 85 percent, both Arizona's shortage and creation volume are 0 kaf.
- If the combined storage of Lake Mead (physical) and Lake Powell (effective) is between 85 percent and 60 percent, Arizona's shortage is 0 kaf and its creation volume is 466.667 kaf.
- If the combined storage of Lake Mead (physical) and Lake Powell (effective) is between 60 percent and 39.83 percent, Arizona's shortage increases from 466.667 kaf to 760 kaf. As the shortage increases, Arizona's creation decreases from 293.333 kaf to 0 kaf. As a result, the sum of Arizona's shortage and creation equals 760 kaf.
- If the combined storage of Lake Mead (physical) and Lake Powell (effective) is less than 39.83 percent, Arizona's shortage is greater than 760 kaf and their creation is 0 kaf.

Table B-15
Summary of Arizona's Assumed Creation Volumes Relative to Shortage in the Enhanced Coordination Alternative

Lake Mead (physical) & Lake Powell (effective) Combined Storage (%)	Arizona Shortage (kaf)	Arizona Annual Creation(kaf)
> 85%	0	0
≤ 85% to > 60%	0	466.667
≤ 60% to ≥ 39.83%	466.667 to 760.000	293.333 to 0
< 39.83%	> 760.000	0

For modeling purposes, CAP and CRIT-AZ create storage credits in the Lake Mead mechanism. The creation volume for each water user is proportional to their annual depletion schedule minus their annual shortage. The following equation is used to calculate each water user's portion of Arizona's total annual creation volume:

$$\begin{aligned} Creation\ Volume_A &= AZ\ Total\ Creation\ Volume\ (af) \\ &\times \frac{(Annual\ Depletion\ Schedule_A - Annual\ Shortage_A)}{\sum Annual\ Depletion\ Schedule_{CAP+CRIT\ AZ} - \sum Annual\ Shortage_{CAP+CRIT\ AZ}} \end{aligned}$$

where "A" is either the CAP or CRIT-AZ water-user. For both water users, an initial portion of the creation volume is first stored in the Protection Pool, subject to the constraints of the Protection Pool and the associated modeling assumptions (see **Section B.6.3.4**), and the remaining volume is stored in the Lake Mead mechanism.

Delivery/Conversion

Arizona is assumed to take delivery of storage credits in the Lake Mead mechanism to mitigate shortages greater than 760 kaf. The following formula is used to determine Arizona's total delivery volume from the Lake Mead mechanism, subject to available storage credits:

$$\begin{aligned} &AZ\ Total\ Delivery\ Volume\ (af) \\ &= Maximum(AZ\ Total\ Annual\ Policy\ Shortage\ (af) - 760{,}000\ (af), 0\ (af)) \end{aligned}$$

The total Arizona delivery is then distributed to CAP and CRIT-AZ, proportional to each water user's annual shortage:

$$Delivery\ Volume_A = AZ\ Total\ Delivery\ Volume\ (af) \times \frac{Annual\ Shortage_A}{\sum Annual\ Shortage_{CAP+CRIT\ AZ}}$$

where "A" is either the CAP or CRIT-AZ water-user.

For modeling purposes only, if CAP is unable to mitigate their portion of the statewide shortage exceeding 760 kaf using their own storage credits, then it is assumed that CRIT-AZ storage credits, followed by IID's storage credits (see **Section B.6.2.4**, *Delivery/Conversion*) are delivered to CAP. The volume of the CRIT-AZ's storage credits that are modeled as deliveries to CAP is limited to the lesser of the storage credits available in CRIT-AZ's account and CAP's remaining unmitigated shortage.

For GRIC's Pre-2027 ICS that is converted to the Lake Mead mechanism on January 1, 2027, the delivery of this water—subject to availability—is modeled using the following logic. While the water is physically delivered to CAP in the model, this approach ensures that the delivery is properly accounted for using GRIC's existing storage credits:

$$\left(AZ\ Total\ Delivery\ Volume \times \frac{Annual\ Shortage_{CAP}}{\sum Annual\ Shortage_{CAP+CRIT\ AZ}}\right) X \left(\frac{200{,}760\ af}{Annual\ Depletion\ Schedule_{CAP}}\right)$$

B.6.2.4 California Creation and Conversion/Delivery Assumptions

For modeling purposes, California's conservation activity is modeled using IID, MWD, and CRIT-California (CA).

Creation

Both MWD and IID's annual conservation volumes are based on the SRWYT, described in **Section B.3.2.4**, California Creation and Delivery Assumptions. **Table B-16** below shows the assumed conservation for MWD and IID:

Table B-16
Summary of MWD and IID Assumed Conservation Volumes in the Enhanced Coordination Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	0.000	0.000	0
D	41.667	0.000	41.667
BN	229.167	125.000	354.167
AN	416.666	166.667	583.333
W	483.333	250.000	733.333

Conservation first goes towards meeting any shortages in the same year it occurs. Any remaining conserved water is stored in the Lake Mead mechanism.

Every three years, CRIT-CA is assumed to store 10 percent of its depletion schedule. The creation volume is reduced by any annual shortage, which depends on the shortage distribution method and the total shortage volume.

Delivery/Conversion

MWD and IID are assumed to convert storage credits in the Lake Mead mechanism to meet shortages that are not met by same-year conservation. They also are assumed to take additional deliveries from their pools, independent of shortage, as shown in the **Table B-17**; both subject to the maximum annual delivery/conversion limit.

Table B-17
Summary of MWD and IID Assumed Delivery Volumes in the Enhanced Coordination Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	125.000	125.000	250.000
D	0.000	62.500	62.500
BN	0.000	0.000	0.000
AN	0.000	0.000	0.000
W	0.000	0.000	0.000

Additionally, for modeling purposes only, it is assumed IID storage credits are delivered to MWD, CAP and/or SNWA if the total Lower Basin shortage exceeds 1.5 maf and there is at least 150 kaf in IID's account after accounting for current-year deliveries/conversions (as described above). These storage credits are assumed to only be used to mitigate each water user's respective shortage attributable to total Lower Basin shortages greater than 1.5 maf. It is assumed that MWD may take delivery of all IID storage credits, if needed, to fully mitigate their portion of the Lower Basin shortage above 1.5 maf. Any remaining IID storage credits are assumed to be distributed between CAP (90 percent) and SNWA (10 percent). Deliveries of IID's storage credits to MWD, CAP, and/or SNWA are modeled to occur after the following assumed, respective, operations are insufficient to mitigate this portion of each water user's shortage:

- MWD storage credits;
- CAP storage credits and the delivery of CRIT-AZ storage credits to CAP; and
- SNWA storage credits and Interstate Water Banking.

CRIT-CA does not take direct delivery of their storage credits in the Lake Mead mechanism. Rather, this water is transferred to CRIT-AZ when CRIT-AZ is unable to mitigate its shortage usings its own storage credits, subject to the following constraints:

- The water may be used only to mitigate CRIT-AZ's shortage; however, mitigation is limited to the portion of CRIT-AZ's shortage associated with total Lower Basin shortages exceeding 1.5 maf.
- Arizona's total shortage exceeds 760 kaf (i.e., total Lower Basin shortage exceeds 1.5 maf)
- Maximum delivery volume is limited to 25 kaf/year.

B.6.2.5 Nevada Creation and Conversion/Delivery Assumptions

Creation

SNWA is modeled to store two types of water in the Lake Mead mechanism: conserved water and Tributary Conservation. With respect to Tributary Conservation, which represents conservation on the Virgin and Muddy Rivers, 35 kaf per year is created. This water is stored in the Lake Mead mechanism if space is available, after the applicable system assessment is applied. In CRSS, this is modeled as a gain to Lake Mead.

For conserved water, SNWA's annual creation is calculated using the following equation:

$$Annual\ Creation = Maximum(\ 300{,}000\ af - Annual\ Shortage_{NV} - Annual\ Demand_{NV}, 0\ af)$$

Based on the assumed depletion schedules, SNWA creates conservation water until 2047, at which point demands equal full apportionment (see **Appendix M**, Lower Division States Depletion Schedules).

Delivery
Water stored in the Lake Mead mechanism is assumed to first mitigate shortages and, if available, then delivered to meet Nevada's demands exceeding apportionment, which starts in 2047. These additional demands range from 2,339 af in 2047 to 40,415 af in 2060 (**Table B-7**).

If there are insufficient storage credits in the Lake Mead mechanism to fully mitigate SNWA's shortages or to satisfy demands exceeding apportionment, SNWA is modeled to take delivery of water stored in the Interstate Water Banks, located in Arizona and California. This mechanism is independent of the Lake Mead mechanism; however, the model contains logic to account for this delivery (**see Section B.3.2.2**). As part of these modeling assumptions, SNWA withdraws from the Arizona bank followed by the California bank subject to the constraints described in **Section B.3.2.2**.

Additionally, if Nevada's account in the mechanism is full or dead pool related reductions occur, SNWA is assumed to take full delivery of its Tributary Conservation.

B.6.2.6 Mexico Creation and Conversion/Delivery Assumptions
Reclamation developed modeling assumptions for the storage and delivery of deferred water by Mexico to evaluate possible impacts of this activity on flow and other resources for this Final EIS.[14] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 U.S.-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty) or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission (IBWC) in consultation with the Department of State.

Creation
Mexico is assumed to create up to 250 kaf per year, depending on its total reduction volume. An overview of the general creation logic is provided below, followed by a summary in **Table B-18**.

- If the combined storage of Lake Mead (physical) and Lake Powell (effective) exceeds 85 percent, both Mexico's reduction and creation volumes are 0 kaf.
- If the combined storage of Lake Mead (physical) and Lake Powell (effective) is between 85 percent and 60 percent, Mexico's reduction is 0 kaf and their creation volume is 250 kaf.
- If the combined storage of Lake Mead (physical) and Lake Powell (effective) is less than 60 percent, Mexico's reduction is greater than or equal to 250 kaf and their creation is 0 kaf.

[14] Assuming activity in Mexico is beneficial for National Environmental Policy Act purposes because it maximizes the effects on river flows as it occurs at the most downstream point in CRSS.

Table B-18
Summary of Mexico's Assumed Creation Volume Relative to Reductions in the Enhanced Coordination Alternative

Lake Mead (physical) & Lake Powell (effective) Combined Storage (%)	Mexico Reduction[A] (kaf)	Mexico Annual Contribution [A] (kaf)
> 85%	0	0
≤ 85% to > 60%	0	250
≤ 60%	≥ 250	0

[A] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico

Delivery/Conversion
Mexico is assumed to convert storage credits to meet assumed delivery reductions that exceed 250 kaf, which occur when the combined storage of Lake Mead (physical) and Lake Powell (effective) is less than or equal to 60 percent. The conversion volume is limited by the available stored credits, the maximum annual delivery/conversion, and are assumed to only occur when Lake Mead's physical elevation is above 1,025 feet.

B.6.3 Lake Mead Mechanism (Protection Pool)

As described in **Appendix S**, the Protection Pool—designed with significant input from representatives of Basin Tribes—would be a pool of water controlled by Reclamation that can reach a maximum volume of 2.0 maf. It would acquire water through multiple mechanisms, including but not limited to system assessments on water user-created conservation, potentially compensated Lower Basin tribal water (conserved consumptive use and unused), system efficiency projects and potentially compensated nontribal conservation. Contents of the Protection Pool would be included in determinations of Lake Powell releases and shortage volumes.

The Protection Pool could be used for a range of purposes, including, but not limited to, meeting federal firming obligations,[15] other federal delivery obligations, protecting Lower Basin water supplies, protecting infrastructure, and providing environmental benefits.

The subsequent sections provide a detailed description of the modeling assumptions and associated constraints.

B.6.3.1 Treatment of Pre-2027 ICS

For modeling purposes, it was intended that GRIC's pre-2027 EC-ICS that was assumed to exist on December 31, 2026 (**Table B-1**) would be converted to the Protection Pool on January 1, 2027. In the Enhanced Coordination Alternative, the existing GRIC EC-ICS (286,708 af) and CRIT-AZ EC-ICS (9,009 af) were erroneously transferred to the Lake Mead mechanism.

[15] The Secretary is obligated to firm certain volumes of CAP non-Indian agricultural water provided as part of Indian water rights settlements to specific tribes in Arizona, under Section 105(a) of the Arizona Water Settlements Act of 2004, Pub. L. 108-451, 118 Stat. 3478.

B.6.3.2 General Assumptions

The maximum capacity of the Protection Pool is 2.0 maf. Annual limits on creation and delivery are not explicitly modeled. The Protection Pool operates on a calendar year to align with reservoir operations. Delivery/conversion from the Lake Mead mechanism – Protection Pool is prohibited if Lake Mead starts the year with a physical pool elevation below 1,025 feet.

Protection Pool conservation activity is modeled using water generated from the following, prioritized, mechanisms:

1. Unused Water from the Lower Division Tribes with Mainstream Entitlements;
2. Lower Basin Tribal Conserved Consumptive Use;
3. System Efficiency;
4. System Assessment; and
5. Non-Tribal Conservation.

It is assumed that when the total conservation volume exceeds the Protection Pool capacity, higher-priority creation mechanisms generate conservation until the Protection Pool reaches full capacity. Additional details on each mechanism and the associated model assumptions are provided in the subsequent sections below.

For all mechanisms, except for water created via System Assessment, it is assumed a one-time system assessment of 7 percent is applied in the year the water is conserved and stored in the Protection Pool. Additionally, there is an annual deduction for evaporation equal to the Protection Pool's proportional share of total evaporation from Lake Mead. The evaporation deduction is applied annually in January based on the previous year's evaporation computed using the RiverWare™ Input Evaporation method and the total volume in the conservation pool at the end of the previous calendar year.

Similarly, conversion/delivery from the Protection Pool is modeled using the following, prioritized, mechanisms:

1. Federal Tribal Firming
2. Lower Basin Shortage Mitigation
3. Deliveries to benefit Lower Colorado River Multi-Species Conservation Program (LCR MSCP) sites

Additional details on the modeling assumptions for the creation and delivery/conversion of storage credits from the Protection Pool are provided below.

B.6.3.3 Contribution

Unused Water from the Lower Division Tribes with Mainstream Entitlements - Creation Assumptions

As noted above, Protection Pool conservation activity is modeled using water generated from five prioritized mechanisms. It is assumed that storing unused water associated with the Lower Division Tribes is the top priority, i.e., if there is limited available space, this water is stored first. Such storage would be voluntary. A table of the explicitly modeled Lower Division Tribes that are assumed to be able to create unused tribal water for storage in the Protection Pool is shown below (**Table B-19**):

These tribes hold diversion entitlements; therefore, for modeling purposes, unused water is calculated as the difference between the depletion equivalent of each of the tribe's entitlement and the assumed depletion schedule for the current year (see **Appendix M**, Lower Division State Depletion Schedules). Additionally, for modeling purposes, it is assumed 10 percent of the unused Lower Basin tribal water can be stored in the Protection Pool. As a result, this water would not be available for diversion and use by lower priority water users—specifically, MWD, CAP and SNWA—and the corresponding volumes are deducted from their modeled demands. **Appendix H**, Sensitivity Analysis - Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative, provides information on the methodology used to estimate the Lower Division States unused tribal water, which was needed to model this concept.

Table B-19
Explicitly Modeled Lower Division Tribes that are Assumed to Create Unused Tribal Water for Storage in the Protection Pool – Enhanced Coordination Alternative.

CRSS Water User	State
Chemehuevi Indian Reservation	California
Cocopah Indian Reservation	Arizona
Colorado River Indian Reservation	Arizona
Colorado River Indian Reservation	California
Fort Mojave Indian Reservation	Arizona
Fort Mojave Indian Reservation	California
Fort Mojave Indian Reservation	Nevada
Fort Yuma Indian Reservation	Arizona
Fort Yuma Indian Reservation	California
Indian Water Rights Settlements[16]	Arizona

Pending available capacity in the Protection Pool, the assumed annual volume of unused tribal water available for storage in the Protection Pool ranges from 7.66 kaf in 2027 to 0 kaf per year in 2040-2060.[17]

[16] Please see **Appendix H** for a description of this line item.
[17] This modeling erroneously includes unused tribal water associated with the Hopi Tribe. As such, the range here does not match 10 percent of the total shown in **Appendix H, Table H-4**. The maximum magnitude of the discrepancy is 868 af in 2039-2060.

Tribal Conserved Consumptive Use Creation

For modeling purposes, tribal conserved consumptive use storage credits are assumed to be generated by the CAP Tribes and CRIT-AZ. In CRSS, CAP's entire Colorado River diversion, with the exception of the Salt River Pima-Maricopa Indian Community and Ak-Chin Indian Community portion of the diversion that is Arizona Priority 3, is represented as a single diversion. As such, this diversion is reduced to model the storage credits that are assumed to be generated by CAP Tribes. Such conservation would be voluntary.

For modeling purposes, it is assumed CAP and CRIT-AZ's tribal conserved consumptive use is an initial portion of each water user's creation volume described in **Section B.6.2.3**, *Creation*. Specifically**,** given the pro rata shortage distribution[18] included in the Enhanced Coordination Alternative, it is assumed CRIT-AZ can create up to 50 kaf per year of tribal conserved consumptive use, and the CAP Tribes can create up to 100 kaf per year of tribal conserved consumptive use. Note, in the modeling, this water was added to the Lake Mead mechanisms but was not properly subtracted from the respective water user's requested depletion schedule. Additionally, a discrepancy in the modeling exists in the calculation of each water user's Tribal Conserved Consumptive Use contribution when the Protection Pool is at capacity. Rather than proportionally reducing contributions based on each user's calculated desired contribution, the model calculates the actual contribution based on each user's proportional creation for the Lake Mead mechanism.

System Efficiency Creation

For modeling purposes, it is assumed that voluntary system efficiency projects generate the System Efficiency storage credits. The creation of this mechanism is phased-in over a three-year period, with 25 kaf in 2027, 50 kaf in 2028, and 75 kaf per year for the remainder of the simulation period (2030-2060). The conservation for this mechanism is modeled by reducing the scheduled demands on the water user that represents the water bypassed pursuant to IBWC Minute 242.

System Assessment Creation

It is assumed a one-time system assessment of 7 percent is applied in the year water is conserved and stored in the Lake Mead mechanism and the Protection Pool. The assessed volume is stored in the Protection Pool as a contribution generated through "System Assessment" activity. Water generated via this activity is not subject to a subsequent system assessment. Any assessed volume that cannot be stored in the Protection Pool becomes system water.

Non-Tribal Creation

It is assumed non-tribal contributions are generated when the Lake Mead water user-controlled pools are at capacity and the respective water users cannot store their full desired annual contribution volume (**see Section B.6.2.2**). Subject to availability in the Protection Pool, a maximum of 300 kaf of non-tribal contributions may be stored in the Protection Pool annually. Each state's share of the 300 kaf annual contribution limit is assumed to be proportional to the

[18] It is assumed these maximum creation limits could change under a priority-based shortage distribution, which is not modeled in the Enhanced Coordination Alternative.

assumed cumulative storage limits modeled for the Lake Mead mechanism and are shown below in **Table B-20**.

Table B-20
Constraints for the Non-Tribal Annual Contributions in the Enhanced Coordination Alternative

Entity	Maximum Annual Contribution (kaf)
Arizona	42
California	114
Nevada	42
Mexico	102
Total	**300**

B.6.3.4 Delivery/Conversion

Federal Tribal Firming Delivery/Conversion Assumptions

As noted above, taking delivery/conversion of storage credits from the Protection Pool is modeled using three prioritized mechanisms. For modeling purposes, it is assumed the highest priority mechanism is the delivery/conversion of storage credits to meet federal tribal firming obligations.

For modeling purposes only, CAP is assumed to take delivery of storage credits in the Protection Pool when shortages exceed specified thresholds as a modeling approximation of federal tribal firming obligations.[19] The modeled maximum annual delivery/conversion volume relative to these shortage thresholds are provided below in **Table B-21**.

Table B-21
CAP Shortage Thresholds Relative to Delivery/Conversion of Storage Credits in the Enhanced Coordination Alternative

Current Year Shortage for CAP (kaf)	Maximum Annual Delivery/Conversion Volume (kaf)
≥ 592	36.924
< 592 to ≥ 512	24.325

[19] Please see the Arizona Water Settlements Act, Pub. L. 108-451, 118 Stat. 3478 (Dec. 10, 2004), section 105, for a general description of the firming program. All firming deliveries in any given year would be made in accordance with applicable law. This appendix is not a legal interpretation of the firming program or of federal obligations. Actual firming deliveries may vary from the modeling approximations contained in this appendix, and Reclamation retains discretion to include legally-required tribal deliveries in this priority mechanism.

Lower Basin Shortage Mitigation Delivery/Conversion Assumptions

Following federal tribal firming, storage credits in the Protection Pool are assumed to be delivered/converted to mitigate Lower Basin shortage. For modeling purposes, this delivery/conversion is assumed to occur, subject to availability, when the annual Lower Basin shortage exceeds 1.8 maf for three consecutive years, at which point up to 300 kaf of storage credits in the Protection Pool are delivered/converted to mitigate Lower Basin shortage. This shortage mitigation is modeled by reducing the annual Lower Basin shortage volume by a quantity equal to the volume delivered/conserved under this mechanism resulting in all Lower Basin users receiving a proportional benefit of the reduced shortage.

LCR MSCP Delivery/Conversion Assumptions

One of the stated uses of the Protection Pool is to provide environmental benefits. As a modeling simplification to represent this in CRSS, storage credits are assumed to be delivered to the Cibola National Wildlife Refuge (NWR). Cibola NWR was chosen as a modeling simplification and approximation as a representative LCR MSCP site. Subject to available storage credits in the Protection Pool, this delivery is modeled as a 40 kaf delivery to the Cibola NWR water user every three years.

B.7 Maximum Operational Flexibility Alternative

The Maximum Operational Flexibility Alternative includes a conservation mechanism that operates differently from those in the other alternatives. The conservation mechanism – referred to as the Conservation Reserve – is a pool that would store water conserved by Colorado River water users in either Basin (including Mexico) and would be distributed strategically across Lake Powell and Lake Mead to protect infrastructure and benefit a range of resources including the Colorado River Delta, LCR MSCP, and Grand Canyon. Reclamation would determine how to allocate the Conservation Reserve volume between reservoirs and could increase or decrease Lake Powell's basic water year release volume to meet infrastructure needs or resource goals. Operation of the Conservation Reserve would not affect tracking of Lee Ferry flows.

B.7.1 Lake Powell and Lake Mead Mechanism

B.7.1.1 General Assumptions

The Conservation Reserve volume in Lake Powell and Lake Mead does not affect the determination of Lake Powell's water year release or Lower Basin/Lake Mead operations, as they are based on effective storage and three-year preceding average natural flow at Lees Ferry. The Conservation Reserve has a maximum volume of 8.0 maf split between Upper and Lower Basin users, with 3.0 maf of space allocated to Upper Basin users and 5.0 maf allocated to Lower Basin users, which includes the storage of pre-2027 ICS. There is no maximum volume in Lake Powell or Lake Mead nor a maximum total storage for any single user or state, though there are Basin-specific total annual creation and delivery limits described in the following sections.

For modeling purposes, the storage credits are stored in Lake Powell or Lake Mead and are exchanged between the two reservoirs. Upper Basin and Lower Basin storage credits are tracked

separately as described in the following sections. Each Basin's storage credits do not sit in one reservoir and are allowed to be exchanged between Lake Powell and Lake Mead. The location of storage credits does not impact any individual water user's ability to take delivery of their conserved water. The following objectives are assumed to govern the exchange of storage credits between Lake Powell and Lake Mead, listed in order of priority, and define how exchange volumes are calculated to achieve each objective:

1. **Protection of critical elevations at Lake Powell (3,510 feet) and Lake Mead (1,000 feet).**

   In January, if Lake Powell or Lake Mead are projected to end the water year below their respective critical elevations, storage credits may be exchanged between the two reservoirs by adjusting the Lake Powell release to protect critical elevations.

2. **Delivery of storage credits to users, including Upper and Lower Basin users, LCR MSCP sites, and the Colorado River Delta.**

   If Lower Basin storage credits are requested for delivery but exceed the Conservation Reserve volume available in Lake Mead, additional storage credits are added to the Lake Powell release to meet the shortfall.

3. **Protection of Grand Canyon resources to support native fish populations, mitigate invasive species, and improve opportunities for high-flow experiments by maintaining Lake Powell elevations between 3,530 and 3,600 feet.**

   In January, the exchange volume is calculated as the difference between the projected end of water year Lake Powell storage and the equivalent storage at elevation 3,570 feet (the modeling target elevation). This exchange volume is then added to the Lake Powell release. Due to uncertainty in projected end of water year storage, the target elevation range may not be fully achieved.

If objectives conflict, the highest-priority objective governs adjustments to the Lake Powell release. Exchanges are assumed to be subject to the following conditions:

- Exchanges from Lake Mead to Lake Powell are constrained to ensure that Lake Powell's minimum daily release does not drop below 6,150 cubic feet per second (cfs)[20] and the basic water year release remains at or above 5.0 maf.
- No exchanges occur if beginning-of-year reservoir elevations are below their respective critical elevations.
- If Lake Powell declines below 3,510 feet any time during the water year, run-of-river operations will govern the Lake Powell release. If this occurs, Conservation Reserve activities affecting the Lake Powell release are suspended for the remainder of the year, and Conservation Reserve balances are reset to their prior end of calendar year values.

[20] A minimum daily release of approximately 7,000 cfs was preferred to support recreation resources; however, the minimum daily release was set at 6,150 cfs in CRSS to avoid conflict with the minimum basic water year release of 5 maf.

B.7.1.2 Upper Basin Mechanism

General Assumptions

The maximum capacity of Upper Basin's Conservation Reserve is 3.0 maf. The conservation creation for the Lake Powell mechanism is modeled as a total Upper Basin volume and not specific to any state or user. At the time of creation, a one-time 10-percent assessment is deducted from the volume.

Creation

Exact volumes of Upper Basin conservation over time are uncertain, but for the purposes of modeling, conservation up to 500 kaf per year is included, with variable annual volumes based on hydrologic conditions. The specific conservation volume is determined by comparing the modeled water year Lees Ferry natural flow to the historical 1991–2020 10th, 40th, and 80th percentile thresholds (**Table B-22**). Linear interpolation is used when the modeled Lees Ferry natural flow falls between percentile thresholds.

Table B-22
Upper Basin Modeled Annual Conservation Volumes in the Maximum Operational Flexibility Alternative

Current Water Year Natural Flow Relative to Historical Flows (1991-2020)	Annual (Water Year) Upper Basin Conservation (kaf)
Current Yr Natural Flow > 80th percentile	500
80th percentile ≥ Current Yr Natural Flow > 40th percentile	300
40th percentile ≥ Current Yr Natural Flow > 10th percentile	200
10th percentile ≥ Current Yr Natural Flow	0

Annual conservation volumes are disaggregated to the monthly scale using the average monthly Upper Basin agricultural demand distribution shown in **Table B-12** (**Section B.6.1.2**). These monthly volumes are then modeled as an inflow above Lake Powell.

Delivery/Conversion

Upper Basin users' conserved water is assumed to be converted to system water based on the shortage curve described in **Appendix S**. When Lower Basin shortages are greater than 2.0 maf, the volume above 2.0 maf is assumed to be converted from Upper Basin users' Conservation Reserve water to system water, subject to availability in the Conservation Reserve. The required Lower Basin shortage volume would be reduced by whatever volume of previously conserved Upper Basin water is converted. Conservation is assumed to not be available for conversion in the year in which it is created.

B.7.1.3 Lower Basin Mechanism

Treatment of Pre-2027 ICS

As described in **Appendix S**, ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be used or converted to the Post-2026 mechanism using a phased approach over 5 years.[21] Once transferred to the new mechanism, it is modeled as being subject to all provisions described herein.

As a modeling simplification, ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 (Pre-2027 ICS; **Table B-1**) is converted to the Post-2026 Lower Basin mechanism on January 1, 2027, and phased into the exclusion of operational determinations (i.e., operational neutrality) over 5 years. Other than the immediate exclusion from operational determinations, the new mechanism provisions—described herein—are modeled as immediately applying to Pre-2027 ICS. Additionally, the Pre-2027 ICS included in operational determinations (i.e., non-operationally neutral), is assumed to be delivered/used before the Pre-2027 ICS that is excluded from operational determinations (i.e., operationally neutral). This may result in the Pre-2027 ICS being fully exhausted before the end of the 5-year transition period.

General Assumptions

The maximum capacity of the Lower Basin mechanism is 5.0 maf,[22] with an annual maximum creation calculated as 3.0 maf minus the total Lower Basin shortage for the year. The maximum delivery is 3.0 maf. The Lower Basin mechanism operates on a calendaryear to align with reservoir operations. There is no delivery of storage credits modeled if Lake Powell or Lake Mead starts the water year below critical elevations, 3,510 feet and 1,000 feet, respectively. Creation volumes are assumed to not be exchanged between Lake Powell and Lake Mead in the year of creation. It is assumed a one-time system assessment of 10-percent is applied in the year the water is conserved and stored.

For modeling purposes, the conservation activity is modeled using the water users in **Table B-23.**

Table B-23
Lower Basin Mechanism Water Users in the Maximum Operational Flexibility Alternative

Water User	Entity
CAP	Arizona
Cibola NWR	Arizona
CRIT-AZ	Arizona
Yuma County Water Users Association (Yuma County WUA)	Arizona
MWD	California
IID	California

[21] The modeling erroneously excludes the conversion of system efficiency ICS to the Lake Mead mechanism.
[22] The 5.4 maf maximum capacity shown in **Table TA 4-13** for the Critically Dry flow category appears to be a modeling error.

Water User	Entity
CRIT-CA	California
SNWA	Nevada
Mexico	Mexico

Arizona Creation and Conversion/Delivery Assumptions

In general, Arizona's creation and delivery of conserved water is inversely related to the state's shortage volume.

Creation

Arizona is assumed to create up to 880 kaf per year, depending on the state's total shortage volume. An overview of the logic is provided below.

- If Arizona's shortage is zero, the creation volume is 0 kaf.
- If Arizona's shortage is 0 to 880 kaf, Arizona's creation linearly decreases from 880 kaf to 0 kaf as Arizona's shortage increases from 0 kaf to 880 kaf.
- If Arizona's shortage is greater than 880 kaf, the creation volume is 0 kaf.

The computed state creation volume is then split to the CAP and CRIT-AZ water-users using the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.3**, *Creation*). The computed state creation volume is then split to the CAP and CRIT-AZ water-users using the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.3**, *Creation*).

Delivery/Conversion

Arizona is assumed to take delivery of storage credits to mitigate shortages greater than 880 kaf, subject to delivery constraints. The water-user delivery logic is identical to the methodology described in Enhanced Coordination Alternative (see **Section B.6.2.3**, *Delivery/Conversion*). Additionally, if CAP is unable to mitigate the portion of shortage that may be offset with storage credits, it is assumed that CAP takes delivery of CRIT-AZ storage credits, followed by an assumed delivery from IID using the methodology described in Enhanced Coordination Alternative (see **Section B.6.2.4**, *Delivery/Conversion*).

California Creation and Conversion/Delivery Assumptions

For modeling purposes, California's conservation activity is modeled using IID, MWD, and CRIT-CA.

Creation

Both MWD and IID's annual conservation volumes are based on the SRWYT, described in **Section B.3.2.4**. **Table B-24** shows the assumed conservation for MWD and IID. **Table B-24** shows the assumed conservation for MWD and IID.

Table B-24
Summary of MWD and IID Assumed Conservation Volumes in the Maximum Operational Flexibility Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	0	0	0
D	50	0	50
BN	275	150	425
AN	500	200	700
W	580	300	880

Conservation is assumed to first go towards meeting any shortages in the same year it occurs. Any remaining conserved water is stored in the Lower Basin mechanism.

Every three years, CRIT-CA is assumed to store 10 percent of its depletion schedule. The creation volume is reduced by any annual shortage.

Delivery/Conversion
MWD and IID are assumed to convert storage credits in the Lake Mead mechanism to meet shortages that are not met by same-year conservation. They also are assumed to take additional deliveries from their pools, independent of shortage, as shown in **Table B-25**; both subject to the maximum annual delivery/conversion limit.

Table B-25
Summary of MWD and IID Assumed Delivery Volumes in the Maximum Operational Flexibility Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	150	150	300
D	0	75	75
BN	0	0	0
AN	0	0	0
W	0	0	0

CRIT-CA's delivery assumptions are identical to those described in the Enhanced Coordination Alternative (see **Section B.6.2.4**, *Delivery/Creation*). Additionally, it is assumed IID storage credits are delivered to MWD, CAP and SNWA using the same methodology as those described in the Enhanced Coordination Alternative (see **Section B.6.2.4**, *Delivery/Conversion*).

Nevada Creation and Conversion/Delivery Assumptions
Nevada's creation and delivery logic is identical to the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.5**).

Mexico Creation and Conversion/Delivery Assumptions

Reclamation developed modeling assumptions for the storage and delivery of deferred water by Mexico to evaluate possible impacts of this activity on flow and other resources for this Final EIS.[23] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Creation

Mexico is assumed to create up to 275 kaf per year, depending on its total reduction volume. An overview of the general creation logic is provided below.

- If Mexico's reduction is zero, the creation volume is 0 kaf.
- If Mexico's reduction is 0 to 275 kaf, Mexico's creation linearly decreases from 275 kaf to 0 kaf as Mexico's reduction increases from 0 kaf to 275 kaf.
- If Mexico's reduction is greater than 275 kaf, the creation volume is 0 kaf.

Delivery/Conversion

Mexico is assumed to convert storage credits to meet assumed delivery reductions that exceed 275 kaf. The conversion volume is limited by the available stored credits and the maximum annual total delivery/conversion and other delivery constraints.

LCR MSCP Creation and Conversion/Delivery Assumptions

One of the stated goals of the Conservation Reserve is to benefit a range of resources including the LCR MSCP. As a modeling simplification to represent this in CRSS, it is assumed that one user in each state creates storage credits in the Conservation Reserve, and then these storage credits are delivered to the Cibola NWR. Cibola NWR was chosen as a modeling simplification and approximation as a representative LCR MSCP site. Conservation Reserve water is assumed to be created and delivered on a three-year creation and delivery cycle, with Conservation Reserve water being created in years one and two and delivered in year three. For modeling purposes, storage credits are generated by the Yuma County Water Users Association (Yuma County WUA) in Arizona, CVWD in California, and SNWA in Nevada.

Creation

Participating water users are assumed to create 22.22 kaf annually for 2 years. Creation will not occur on year three of the creation and delivery cycle, when deliveries are assumed to be made to support the MSCP sites. This creation will allow the delivery of 40 kaf of Conservation Reserve storage credits to be made in year three and accounts for the system assessment applied to the creation of Conservation Reserve storage credits in years one and two.

[23] Assuming activity in Mexico is beneficial for National Environmental Policy Act purposes because it maximizes the effects on river flows as it occurs at the most downstream point in CRSS.

Creation by each water user (Yuma County WUA, CVWD, or SNWA) is proportional to their use in the current year, adjusted for the water user's shortage. It can be computed using the equation:

$$Creation_A = \frac{SDepl_A - Shortage_{Water\ User\ A}}{\sum SDepl_{Yuma\ County\ WUA\ ,Coachella,SNWA} - \sum Shortage_{Yuma\ County\ WUA,Coachella,SNWA}}$$

where:

$Creation_A$ = water user's creation volume

$SDepl_A$ = water user's depletion schedule for the current year

$Shortage_{Water\ User\ A}$ = The water user's shortage for the current year

$\sum SDepl_{Yuma\ County\ WUA,\ CVWD,\ SNWA}$ = sum of Yuma County WUA, CVWD, and SNWA's depletion schedules for the current year

$\sum Shortage_{Yuma\ County\ WUA,\ CVWD,\ SNWA}$ = sum of Yuma County WUA, CVWD, and SNWA's shortage for the current year

Delivery/Conversion

On year three of the three-year creation and delivery cycle, 40 kaf of Conservation Reserve storage credits are assumed to be delivered to the Cibola NWR.

Colorado River Delta Creation and Conversion/Delivery Assumptions

One of the stated goals of the Conservation Reserve is to benefit a range of resources including the Colorado River Delta. For modeling purposes, the conservation activity to benefit the Colorado River Delta is modeled using Mexico.[24] The creation and deliveries to benefit the Colorado River Delta are modeled on a three-year cycle, with creation occurring every year and deliveries occurring every third year.

Creation/Conversion

Mexico is assumed to create 48,214.3 af annually to support a 135 kaf delivery to the delta every three years. On year three of the three-year creation and delivery cycle, Mexico creates water for the delta but is not charged the system assessment as the volumes is taken as a delivery in the same year. The annual creation volume is 1/3 of the desired Conservation Reserve delivery to the delta, adjusted for the system assessment in 2 out of 3 years.

[24] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussion regarding the proposed federal action and implementation of the 1944 Treaty with Mexico through the IBWC in consultation with the Department of State.

Delivery
Delivery of 135 kaf is assumed to occur every three years. This delivery is distributed equally over the months of June and July, with 67.5 kaf being delivered each month.

B.8 Supply Driven Alternative

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) includes a Lake Powell mechanism and a Lake Mead mechanism. Details on each mechanism including creation, delivery, and constraints are provided below.

B.8.1 Lake Powell Mechanism

As described in **Appendix S**, water conserved by Upper Basin users would be stored in a pool in Lake Powell that could reach a maximum volume of 3.0 maf. Upper Division States and Upper Basin Tribes would be able to contribute to the conservation pool and could use their conserved water in intra- and interstate transactions with other Upper Basin users. Water in the Lake Powell conservation pool could be released if needed to meet the determined water year volume. No modeling assumptions were developed to represent these specific uses of water in the Lake Powell conservation pool in the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches).

B.8.1.1 General Assumptions

The volume of water in the Lake Powell conservation pool does not affect the determination of Lake Powell's water year release, as the release is computed solely based on the preceding three-year average natural flow at Lees Ferry, nor does it affect Lower Basin/Lake Mead operations as they are based on Lake Mead elevation. There is a maximum capacity of 3.0 maf. There are no assumed state-specific limitations on the maximum accumulation, nor are there state-specific annual creation or delivery limits, as conservation creation for the Lake Powell mechanism is modeled as a total Upper Basin volume.

There is an annual deduction for evaporation equal to the conservation pool's proportional share of total evaporation from Lake Powell. The evaporation deduction is modeled annually in October based on the previous year's evaporation computed using the RiverWare™ Periodic Net Evaporation method and the total volume in the conservation pool at the end of the previous water year.

B.8.1.2 Creation

Exact volumes of Upper Basin conservation over time are uncertain, but for the modeling purposes, conservation volumes up to 200 kaf may be added in any given year, depending on hydrologic conditions. The modeled conservation volume is determined by comparing the modeled water year Lees Ferry natural flow to the historical 1991–2020 25th and 75th percentile thresholds (**Table B-26**). Linear interpolation is used when the modeled Lees Ferry natural flow falls between 10.60 and 16.5 maf—with conservation increasing from 0 to 200 kaf as natural flow increases across this range.

Table B-26
Upper Basin Modeled Annual Conservation Volumes in the Supply Driven Alternative

Current Water Year Lees Ferry Natural Flow (maf)	Annual (Water Year) Upper Basin Conservation (kaf)
> 16.50[25]	200
Between 16.50 and 10.60[26]	200 to 0 (linear interpolation)
≤ 10.60	0

Annual conservation volumes are disaggregated to the monthly scale using the average monthly Upper Basin agricultural demand distribution shown in **Table B-12** (**Section B.6.1.2**). These monthly volumes are then modeled as inflow above Lake Powell.

If the Lake Powell mechanism reaches full capacity, annual conservation continues; however, the conserved volumes are assumed to be system water rather than being accounted for within the Lake Powell mechanism.

B.8.1.3 Delivery/Conversion

There is no assumed conversion or delivery of storage credits in the Lake Powell mechanism, but water in the Lake Powell conservation pool can be released if needed to meet the determined water year volume.

B.8.2 Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in Lake Mead in a pool that could reach a maximum volume of 8.0 maf (including Pre-2027 ICS). Water users could contribute, convert or deliver water previously stored under this new mechanism at their discretion, within the mechanism's applicable constraints. All storage credits in the Lake Mead conservation mechanism would be excluded from determinations of shortage volumes. The subsequent sections provide a detailed description of the modeling assumptions and associated constraints.

B.8.2.1 Treatment of Pre-2027 ICS

The conversion of pre-2027 ICS to the Post-2026 Lake Mead mechanism is identical to the methodology described in the Maximum Operational Flexibility Alternative except the pre-2027 ICS is phased to the new mechanism over 10 years (see **Section B.7.1.3**, *Treatment of Pre-2027 ICS*).[27]

B.8.2.2 General Assumptions

The maximum capacity of the Lake Mead mechanism, along with individual annual creation and delivery limits, is provided in **Table B-27** below. The Lake Mead mechanism operates on a calendar year to align with reservoir operations. Delivery/conversion from the Lake Mead mechanism is

[25] Historical 1991–2020 75th percentile Lees Ferry natural flow value.
[26] Historical 1991–2020 25th percentile Lees Ferry natural flow value.
[27] The modeling erroneously excludes the conversion of system efficiency ICS to the Lake Mead mechanism.

assumed to be prohibited if Lake Mead starts the year with a physical pool elevation below 1,025 feet.[28]

Table B-27
Lake Mead Mechanism Modeled Limitations of Storage of Conserved Water in Supply Driven Alternative

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery (kaf)
Arizona	880	3,000	465
California	880	3,000	745
Nevada	225	1,000	90
Mexico[1]	500	1,000	100
TOTAL	**2,485**	**8,000**	**1,400**

[1] Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The conservation activity is modeled using the water users in **Table B-28**.

Table B-28
Lake Mead Mechanism Water Users in the Supply Driven Alternative

Water User	Entity
CAP	Arizona
CRIT-AZ	Arizona
MWD	California
IID	California
CRIT-CA	California
SNWA	Nevada
Mexico	Mexico

It is assumed a one-time system assessment of 5 percent is applied in the year the water is conserved and stored. In every subsequent year, the evaporation assessment is assumed to be 3 percent of the stored volume. If water is created and delivered in the same calendar year, no assessments are applied.

[28] The logic included in CRSS erroneously did not apply this constraint to the delivery/conversion of California's storage credits.

B.8.2.3 Arizona Creation and Conversion/Delivery Assumptions

In general, Arizona's delivery of conserved water is inversely related to the effective elevation at Lake Mead and the state shortage volume.

For modeling purposes, Arizona's conservation activity is modeled using CAP and CRIT-AZ.

Creation

Arizona is modeled to create up to 880 kaf per year, depending on the state's total shortage volume. An overview of the logic is provided below, followed by a summary in **Table B-29**.

- If Lake Mead effective elevation is greater than or equal to 1,165 feet, both Arizona's shortage and creation volume are 0 kaf.
- If the Lake Mead effective elevation is between 1,165 feet and 1,145 feet (inclusive), Arizona's shortage is 0 kaf. However, their creation volume increases from 0 kaf to 880 kaf as the effective elevation decreases within this range.
- If the Lake Mead effective elevation is between 1,145 feet and 1,125 feet (inclusive), Arizona's shortage increases from 0 kaf to 760 kaf. As the shortage increases, Arizona's creation decreases from 880 kaf to 440 kaf. As a result, the sum of Arizona's shortage and creation increases linearly from 880 kaf to 1,200 kaf.
- If the Lake Mead effective elevation is between 1,125 feet and 1,050 feet (inclusive), Arizona's creation remains static at 440 kaf. As a result, the sum of Arizona's shortage (760 kaf) and creation (440 kaf) equals 1,200 kaf.
- If the Lake Mead effective elevation is less than 1,050 feet, Arizona's creation decreases from 440 kaf to 0 kaf as shortages increase.

Table B-29
Summary of Arizona's Assumed Creation Volumes Relative to Shortage in the Supply Driven Alternative

Lake Mead Effective Elevation (feet)	Arizona Shortage (kaf)	Arizona Annual Creation (kaf)
≥ 1,165	0	0
< 1,165 to ≥ 1,145	0	0 to 880
< 1,145 to ≥ 1,125	0 to 760	880 to 440
< 1,125 to ≥ 1,050	760	440
< 1,050	> 760	440 to 0

The computed state creation volume is then split to the CAP and CRIT-AZ water users using the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.3**, *Creation*).

Delivery/Conversion

Arizona is assumed to take delivery of storage credits to mitigate shortages greater than 760 kaf, subject to delivery constraints. The water-user delivery logic is identical to the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.3**, *Delivery/Conversion*).

B.8.2.4 California Creation and Conversion/Delivery Assumptions

For modeling purposes, California's conservation activity is modeled using IID, MWD, and CRIT CA.

Creation

Both MWD and IID's annual conservation volumes are based on the SRWYT, described in **Section B.3.2.4**. The assumed conservation for MWD and IID is the same as the Maximum Operational Flexibility Alternative (**Table B-24**). Conservation is assumed to first go towards meeting any shortages in the same year it occurs. Any remaining conserved water is stored in the Lake Mead pool.

Every three years, CRIT-CA is assumed to store 10 percent of its depletion schedule. The creation volume is reduced by any annual shortage, which depends on the shortage distribution method and Lake Mead elevation.

Delivery/Conversion

MWD and IID are assumed to convert storage credits in the Lake Mead mechanism to meet shortages that are not met by same-year conservation. They are also assumed to take additional deliveries from their pools, independent of shortage; both are subject to the maximum annual delivery/conversion limit. Delivery volumes are the same as the Maximum Operational Flexibility Alternative (**Table B-25**).

CRIT-CA's delivery assumptions are identical to those described in Enhanced Coordination Alternative (see **Section B.6.2.4**, *Delivery/Conversion*).

B.8.2.5 Nevada Creation and Conversion/Delivery Assumptions

Nevada's creation and delivery logic is identical to the methodology described in Enhanced Coordination Alternative (see **Section B.6.2.5**, *Delivery*).

B.8.2.6 Mexico Creation and Conversion/Delivery Assumptions

Reclamation developed modeling assumptions for the storage and delivery of deferred water by Mexico to evaluate possible impacts of this activity on flow and other resources for this Final EIS.[29] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In general, the volumes of creation and delivery depend on the assumed annual delivery reductions to Mexico, and the storage credits are used to mitigate these delivery reductions.

[29] Assuming activity in Mexico maximizes the effects on river flows as it occurs at the most downstream point in CRSS.

Creation

Mexico is assumed to create up to 500 kaf per year, depending on its total reduction volume. An overview of the general creation logic is provided below, followed by a summary in **Table B-30**.

- If Lake Mead effective elevation is greater than or equal to 1,145 feet, both Mexico's reductions and creation volume are 0 kaf.
- If the Lake Mead effective elevation is between 1,145 feet and 1,125 feet, Mexico's reductions increase from 0 kaf to 250 kaf. As the reductions increase, Mexico's creation decreases from 250 kaf to 0 kaf. As a result, the sum of Mexico's reductions and creation equals 250 kaf.
- If the Lake Mead effective elevation is less than 1,125 feet, Mexico's creation is 0 kaf.

Table B-30
Summary of Mexico's Assumed Creation Volume Relative to Reductions in the Supply Driven Alternative

Lake Mead Effective Elevation (feet)	Mexico Reduction[B] (kaf)	Mexico Annual Contribution[B] (kaf)
≥ 1,145[A]	0	0
< 1,145 to ≥ 1,125	0 to 250	250 to 0
< 1,125	> 250	0

[A] Mexico is assumed to create 500 kaf in the first year following flood control, and this can occur only once per trace.
[B] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

Additionally, Mexico is assumed to create 500 kaf in the first year following flood control surplus, and this can occur only once per trace.

Delivery/Conversion

Mexico is assumed to convert storage credits to meet assumed delivery reductions that exceed 250 kaf (which occur when Lake Mead's effective elevation is below 1,050 feet). The conversion volume is limited by the available stored credits, the maximum annual delivery/conversion, and are assumed to only occur when Lake Mead's physical elevation is above 1,025 feet.

B.9 Representative Preferred Alternative

The Representative Preferred Alternative includes three pools to store, convert and deliver water for the benefit of water users and the system: the Lake Powell mechanism, the water user-controlled Lake Mead mechanism, and the Lake Mead Federally Managed Water Resources Pool, which was informed by a group of Basin Tribes and would be controlled by Reclamation for Lower Basin-wide benefits. The design of these mechanisms supports proactive conservation and water user flexibility.

Details on modeling assumptions for each mechanism including contribution, delivery, and associated constraints are provided below.

B.9.1 Lake Powell Mechanism

As described in **Chapter 2**, water conserved by Upper Basin users would be stored in a pool in Lake Powell that could reach a maximum volume of 3.0 maf. Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool and to use their conserved water in intra- and interstate transactions with other Upper Basin users; however, no modeling assumptions were developed to model those specific transactions in the Representative Preferred Alternative. Additionally, no modeling assumptions were developed to represent specific uses of water in the Lake Powell conservation pool in the Representative Preferred Alternative.

B.9.1.1 General Assumptions

The volume of water in the Lake Powell conservation pool is included in the determination of Lake Powell's water year release, which is based on the physical pool elevation at Lake Powell. There is a maximum capacity of 3.0 maf. There are no assumed state-specific limitations on the maximum accumulation, nor are there state-specific annual contribution or delivery limits, as conservation contribution for the Lake Powell mechanism is modeled as a total Upper Basin volume.

An annual evaporation assessment of 3 percent is applied to the volume of water remaining in the conservation pool at the end of each water year. The assessment is deducted in October based on the total volume stored at the end of the preceding water year. Additionally, a one-time assessment of 10 percent is applied in the year the water is initially conserved and stored.

B.9.1.2 Contribution

Exact volumes of Upper Basin conservation over time are uncertain, but for the modeling purposes, conservation volumes up to 200 kaf may be added in any given year, depending on hydrologic conditions. The modeled conservation volume is determined by comparing the modeled water year Lees Ferry natural flow to the historical 1991–2020 25th and 75th percentile thresholds (**Table B-31**). Linear interpolation is used when the modeled Lees Ferry natural flow falls between 10.6 and 16.5 maf—with conservation increasing from 0 to 200 kaf as natural flow increases across this range.

Table B-31
Upper Basin Modeled Annual Conservation Volumes in the Representative Preferred Alternative

Current Water Year Lees Ferry Natural Flow (maf)	Annual (Water Year) Upper Basin Conservation (kaf)
> 16.50[30]	200
Between 16.50 and 10.60[31]	200 to 0 (linear interpolation)
≤ 10.60	0

[30] Historical 1991–2020 75th percentile Lees Ferry natural flow value.
[31] Historical 1991–2020 25th percentile Lees Ferry natural flow value.

Annual conservation volumes are disaggregated to the monthly scale using the average monthly Upper Basin agricultural demand distribution shown in **Table B-12** (**Section B.6.1.2**). These monthly volumes are then modeled as inflow above Lake Powell.

If the Lake Powell mechanism reaches full capacity, annual conservation continues; however, the conserved volumes are assumed to be system water rather than being accounted for within the Lake Powell mechanism.

Note, this is the same approach implemented in the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches).

B.9.1.3 Delivery/Conversion

The same approach is implemented as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches): there is no assumed conversion or delivery of storage credits from the Lake Powell mechanism, but water in the Lake Powell conservation pool can be released if needed to meet the determined water year volume.

B.9.2 Lake Mead Mechanism

As described in **Chapter 2**, this pool represents the water user-controlled Lake Mead mechanism. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users. Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 7.0 maf, which includes the storage of pre-2027 ICS. Water users could contribute and convert or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool. All conserved storage credits in Lake Mead would be included in determination of Lower Basin surplus and shortage volumes and equalization releases from Lake Powell.

The subsequent sections provide a detailed description of the modeling assumptions and associated constraints.

B.9.2.1 Treatment of Pre-2027 ICS

For modeling purposes only, ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 is converted to the Post-2026 Lake Mead water-user controlled mechanism on January 1, 2027.

B.9.2.2 General Assumptions

The Lake Mead mechanism operates on a calendar year to align with reservoir operations. The maximum capacity of the Lake Mead mechanism and the individual annual contribution and delivery limits are provided in **Table B-32** below.

Table B-32
Lake Mead Mechanism Modeled Limitations of Storage of Conserved Water in the Representative Preferred Alternative

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery[2] (kaf)
Arizona	880	2,300	430
California	880	2,300	430
Nevada	100	900	140
Mexico[1]	500	1,500	200[3]
TOTAL	**2,360**	**7,000**	**1,200**

1) Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
2) The Representative Preferred Alternative maintained the total U.S. annual delivery of 1.0 maf from the 2007 Interim Guidelines. For modeling purposes, to maximize reach impacts, and to integrate with other modeling assumptions, e.g., demand schedules, the state specific maximums were modified from those in the 2007 Interim Guidelines; this modeling assumption is not intended to determine any future state maximum delivery constraints.
3) The 1944 Water Treaty authorizes scheduled delivery of up to 200 kaf in excess of the 1.5 annual allotment to Mexico.

For modeling purposes only, additional general delivery/conversion constraints include the following:

- Delivery/conversion from the Lake Mead mechanism is prohibited when Lake Mead begins the year with a physical pool elevation below 1,000 feet and is limited to 50 percent of the maximum annual delivery/conversion volume (**Table B-32**) when Lake Mead begins the year with a physical pool elevation between 1,000 and 1,025 feet.
- Delivery/conversion of stored water from the Lake Mead mechanism is limited such that a state's annual apportionment or Mexico's annual allotment is not exceeded when the Lower Basin shortage is greater than or equal to 1.5 maf (i.e., when Lake Mead's physical pool elevation is less than or equal to 1,125 feet). The delivery/conversion is not subject to those constraints when the Lower Basin shortage is less than 1.5 maf (i.e., when Lake Mead's physical pool elevation exceeds 1,125 feet).
- Delivery/conversion of existing DCP ICS (Arizona) and BWSCP credits (Mexico) is allowed when Lake Mead's physical pool elevation exceeds 1,110 feet.

The conservation activity is modeled using the following water users:

Table B-33
Lake Mead Mechanism Water Users in the Representative Preferred Alternative

Water User	Entity
CAP	Arizona
CRIT-AZ	Arizona
MWD	California
IID	California
CRIT-CA	California
SNWA	Nevada
Mexico	Mexico

At the time the water is conserved, a one-time three percent system assessment, along with a one-time seven percent assessment allocated to the Federally Managed Water Resources Pool, for a total assessment of 10 percent are assumed to be applied. The volume allocated to the Federally Managed Water Resources Pool as "System Assessment" storage credits is subject to the Federally Managed Water Resources Pool's constraints and associated modeling assumptions (**See Section B.9.3.3**). If water is created and delivered in the same calendar year, no system assessment is applied.

Additionally, an annual evaporation deduction of 3 percent is applied in January based on the volume of water remaining in the conservation pool at the end of the preceding calendar year.

B.9.2.3 Arizona Contribution and Conversion/Delivery Assumptions

In general, Arizona's contribution and delivery of conserved water is inversely related to the physical elevation at Lake Mead and the state shortage volume.

For modeling purposes, Arizona's conservation activity is modeled using CAP and CRIT-AZ.

Contribution

Arizona is modeled to create up to 880 kaf per year, depending on the state's total shortage volume. An overview of the logic is provided below, followed by a summary in **Table B-34**.

- If Lake Mead physical pool elevation is greater than or equal to 1,165 feet, both Arizona's shortage and contribution volume are 0 kaf.
- If the Lake Mead physical pool elevation is between 1,165 feet and 1,145 feet (inclusive), Arizona's shortage is 0 kaf. However, their contribution volume linearly increases from 0 kaf to 880 kaf as the physical elevation decreases within this range.
- If the Lake Mead physical pool elevation is less than 1,145 feet, the contribution equals 1,200 kaf minus Arizona's Policy Shortage, resulting in decreasing contribution volumes as the shortage increases from zero. The maximum annual contribution is 880 kaf.

Table B-34
Summary of Arizona's Assumed Contribution Volumes Relative to Shortage in the Representative Preferred Alternative

Lake Mead Physical Elevation (feet)	Arizona Shortage (kaf)	Arizona Annual Contribution (kaf)
≥ 1,165	0	0
< 1,165 to ≥ 1,145	0	0 to 880
< 1,145	> 0	880 to 0

The computed state contribution volume is then split to the CAP and CRIT-AZ water users using the methodology described in the Enhanced Coordination Alternative (see **Section B.6.2.3**, *Creation*). For modeling purposes, it is assumed that the first 50 kaf of conserved water generated by CAP and the first 100 kaf of conserved water generated by CRIT-AZ are stored in the Lake Mead mechanism – Federally Managed Water Resources Pool and accounted for as tribal conserved consumptive use (see **Section B.9.3.3**, *Lower Basin Tribal Conserved Consumptive Use Contribution*).

Delivery/Conversion

Arizona is assumed to take delivery of storage credits in the Lake Mead mechanism to mitigate shortages greater than 760 kaf. The following formula is used to determine Arizona's total delivery volume from the Lake Mead mechanism, subject to available storage credits:

$$AZ\ Total\ Delivery\ Volume\ (af) = Maximum(AZ\ Total\ Annual\ Policy\ Shortage\ (af) - 760{,}000\ (af), 0\ (af))$$

The total Arizona delivery is then distributed to CAP and CRIT-AZ, proportional to each water user's annual shortage:

$$Delivery\ Volume_A = AZ\ Total\ Delivery\ Volume\ (af) \times \frac{Annual\ Shortage_A}{\sum Annual\ Shortage_{CAP+CRIT\ AZ}}$$

where "A" is either the CAP or CRIT-AZ water-user.

For modeling purposes only, if CAP is unable to mitigate their portion of the statewide shortage exceeding 760 kaf using their own storage credits, then it is assumed that CRIT-AZ storage credits, followed IID's storage credits (see **Section B.9.2.4**, *Delivery/Conversion*) are delivered to CAP. The volume of the CRIT-AZ's storage credits that are modeled as deliveries to CAP is limited to the lesser of the storage credits available in CRIT-AZ's account and CAP's remaining unmitigated shortage.

To analyze the maximum impact of the total maximum delivery constraints (**Table B-32**) CAP is assumed to take delivery of 430 kaf of storage credits, if the following conditions are all met:

- The previous year total Lower Basin shortage was 1.5 maf, i.e., Lake Mead was below 1,125 feet
- Lake Mead's elevation is above 1,125 feet at the beginning of the current year

- Arizona, Nevada and Mexico's pools within the Lake Mead mechanism all contain sufficient water to meet their respective maximum annual deliveries (**Table B-32**). Note that California's maximum annual delivery is determined using different logic based on the SRWYT, as described in **Section B.3.2.4**. As such, this logic does not apply to California.
- The maximum delivery has not previously occurred, i.e., this maximum delivery may occur at most once per trace.

B.9.2.4 California Contribution and Conversion/Delivery Assumptions

For modeling purposes, California's conservation activity is modeled using IID, MWD, and CRIT-CA.

Contribution

Both MWD and IID's annual conservation volumes are based on the SRWYT, described in **Section B.3.2.4**. **Table B-35** shows the assumed conservation for MWD and IID.

Table B-35
Summary of MWD and IID Assumed Conservation Volumes in the Representative Preferred Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	0	0	0
D	50	0	50
BN	275	150	425
AN	500	200	700
W	580	300	880

Conservation is assumed to first go towards meeting any shortages in the same year it occurs. Any remaining conserved water is stored in the Lake Mead mechanism.

Every three years, CRIT-CA is assumed to store 10 percent of its depletion schedule. The contribution volume is reduced by any annual shortage.

Delivery/Conversion

MWD and IID are assumed to convert storage credits in the Lake Mead mechanism to meet shortages that are not met by same-year conservation. They also are assumed to take additional deliveries from their pools, independent of shortage, as shown in **Table B-36**; both subject to the maximum annual delivery/conversion limit.

Table B-36
Summary of MWD and IID Assumed Delivery Volumes in the Representative Preferred Alternative

SRWYT	MWD (kaf)	IID (kaf)	Total (kaf)
C	215	215	430
D	0	75	75
BN	0	0	0
AN	0	0	0
W	0	0	0

Additionally, for modeling purposes only, it is assumed IID storage credits are delivered to MWD, CAP and/or SNWA if the total Lower Basin shortage exceeds 1.5 maf and there is at least 150 kaf in IID's pool after accounting for current-year deliveries/conversions (as described above). These deliveries are assumed to only be used to mitigate each water user's respective shortage attributable to total Lower Basin shortages greater than 1.5 maf. It is assumed that MWD may take delivery of all IID storage credits, if needed, to fully mitigate their portion of the Lower Basin shortage above 1.5 maf. Any remaining IID storage credits are assumed to be distributed between CAP (90 percent) and SNWA (10 percent). Deliveries of IID's storage credits to MWD, CAP, and/or SNWA are modeled to occur after the following assumed, respective, deliveries are insufficient to mitigate this portion of each water user's shortage:

- MWD storage credits;
- CAP storage credits and the delivery of CRIT-AZ storage credits to CAP; and
- SNWA storage credits and Interstate Water Banking.

CRIT-CA's is assumed to not take direct delivery of their storage credits from the Lake Mead mechanism. Rather, this water is delivered to CRIT-AZ when CRIT-AZ is unable to mitigate its shortage usings its own storage credits, subject to the following constraints:

- The water may be used only to mitigate CRIT-AZ's shortage; however, mitigation is limited to the portion of CRIT-AZ's shortage associated with total Lower Basin shortages exceeding 1.5 maf.
- Maximum delivery volume is limited to 25 kaf/year.

B.9.2.5 Nevada Contribution and Conversion/Delivery Assumptions

Contribution

SNWA is modeled to store two types of water in the Lake Mead mechanism: conserved water and Tributary Conservation. With respect to Tributary Conservation, which represents conservation on the Virgin and Muddy Rivers, 35 kaf per year is created. This water is stored in the Lake Mead mechanism if space is available, after the applicable system assessment is applied. In CRSS, this is modeled as a gain to Lake Mead.

For conserved water, SNWA's annual contribution is calculated using the following equation:

$$Annual\ Creation = Maximum(\ 300{,}000\ af - Annual\ Shortage_{NV} - Annual\ Demand_{NV}, 0\ af)$$

Based on the assumed depletion schedules, SNWA may create conservation water until 2047 depending on the annual shortage volume, at which point demands equal full apportionment (see **Appendix M**, Lower Division States Depletion Schedules).

Delivery

In general, water stored in the Lake Mead mechanism is assumed to first mitigate shortages and, if available, then delivered to meet Nevada's demands exceeding apportionment, which starts in 2047. These additional demands range from 2,339 af in 2047 to 40,415 af in 2060 (**Table B-7**).

If there are insufficient storage credits in the Lake Mead mechanism to fully mitigate SNWA's shortages or to satisfy demands exceeding apportionment, SNWA is modeled to take delivery of water stored in the Interstate Water Banks, located in Arizona and California. This mechanism is independent of the Lake Mead mechanism; however, the model contains logic to account for this delivery (**see Section B.3.2.2**). As part of these modeling assumptions, SNWA withdraws from the Arizona bank followed by the California bank subject to the constraints described in **Section B.3.2.2**.

Additionally, if Nevada's account in the mechanism is full or dead pool related reductions occur, SNWA is assumed to take full delivery of its Tributary Conservation.

To analyze the maximum impact of the total maximum delivery constraints (**Table B-32**) SNWA is assumed to take delivery of 140 kaf of storage credits, if the following conditions are all met:

- The previous year total Lower Basin shortage was 1.5 maf, i.e., Lake Mead was below 1,125 feet
- Lake Mead's elevation is above 1,125 feet at the beginning of the current year
- Arizona, Nevada and Mexico's pools within the Lake Mead mechanism all contain sufficient water to meet their respective maximum annual deliveries (**Table B-32**). Note that California's maximum annual delivery is determined using different logic based on the SRWYT, as described in **Section B.3.2.4.** As such, this logic does not apply to California.
- The maximum delivery has not previously occurred, i.e., this maximum delivery may occur at most once per trace.

B.9.2.6 Mexico Contribution and Conversion/Delivery Assumptions

Reclamation developed modeling assumptions for the storage and delivery of deferred water by Mexico to evaluate possible impacts of this activity on flow and other resources for this EIS.[32] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions

[32] Assuming activity in Mexico maximizes the effects on river flows as it occurs at the most downstream point in CRSS.

regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In general, the volumes of contribution and delivery depend on the assumed annual delivery reductions to Mexico, and the storage credits are used to mitigate these delivery reductions.

Contribution

Mexico is assumed to create up to 500 kaf per year, depending on its total reduction volume. An overview of the general contribution logic is provided below, followed by a summary in **Table B-37**.

- If the Lake Mead physical pool elevation is greater than 1,165 feet, Mexico's reduction and contribution volume are 0 kaf.
- If the Lake Mead physical pool elevation is between 1,165 feet and 1,145 feet (inclusive), Mexico's reduction is 0 kaf and their contribution volume is 250 kaf.
- If the Lake Mead physical pool elevation is less than 1,145 feet, the contribution equals 250 kaf minus Mexico's reduction, resulting in decreasing contribution volumes as the reduction increases from zero.

Table B-37
Summary of Mexico's Assumed Contribution Volume Relative to Reductions in the Representative Preferred Alternative

Lake Mead Physical Elevation (feet)	Mexico Reduction[B] (kaf)	Mexico Annual Contribution[B] (kaf)
> 1,165[A]	0	0
≤ 1,165 to ≥ 1,145	0	250
< 1,145	0 to 250	250 to 0

[A] Mexico is assumed to create 500 kaf in the first year following flood control, and this can occur only once per trace.
[B] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

Additionally, Mexico is assumed to create 500 kaf in the first year following flood control surplus, and this can occur only once per trace.

Delivery/Conversion

In general, Mexico is assumed to take delivery of storage credits from the Lake Mead mechanism to mitigate assumed delivery reductions greater than 250 kaf.

To analyze the maximum impact of the total maximum delivery constraints (**Table B-32**) Mexico is assumed to take delivery of 200 kaf of storage credits, if the following conditions are all met:

- The previous year total Lower Basin shortage was 1.5 maf, i.e., Lake Mead was below 1,125 feet
- Lake Mead's elevation is above 1,125 feet at the beginning of the current year

- Arizona, Nevada and Mexico's pools within the Lake Mead mechanism all contain sufficient water to meet their respective maximum annual deliveries (**Table B-32**). Note that California's maximum annual delivery is determined using different logic based on the SRWYT, as described in **Section B.3.2.4.** As such, this logic does not apply to California.
- The maximum delivery has not previously occurred, i.e., this maximum delivery may occur at most once per trace.

B.9.3 Lake Mead Mechanism (Federally Managed Water Resources Pool)

As described in **Chapter 2**, the Federally Managed Water Resources Pool is a pool of water in Lake Mead established by Reclamation that is anticipated to be around 450 kaf, but could reach a maximum volume of 1.0 maf[33]; for modeling purposes it was assumed the maximum capacity was 1.0 maf. It could acquire water through multiple mechanisms involving acquisition of conserved consumptive use water including but not limited to ICS. Contents of the Pool would be included in determinations of Lake Powell equalization releases and Lower Basin surplus and shortage volumes.

Chapter 2 provides a description of the range of purposes contemplated for the Federally Managed Water Resources Pool. The subsequent sections provide a detailed description of the modeling assumptions and associated constraints used to represent the Federally Managed Water Resources Pool in the Representative Preferred Alternative.

B.9.3.1 Treatment of Pre-2027 ICS

For modeling purposes, GRIC's and CRIT-AZ's pre-2027 EC-ICS that were assumed to exist on December 31, 2026 (**Table B-1**) was converted to the Federally Managed Water Resources Pool on January 1, 2027.

B.9.3.2 General Assumptions

The maximum capacity of the Federally Managed Water Resources Pool is 1.0 maf. Annual limits on contribution and delivery are not explicitly modeled. The Federally Managed Water Resources Pool operates on a calendar year to align with reservoir operations. Delivery/conversion from the Lake Mead mechanism – Federally Managed Water Resources Pool are prohibited if Lake Mead starts the year with a physical pool elevation below 1,000 feet.

Federally Managed Water Resources Pool conservation activity is modeled using water generated from the following, prioritized, mechanisms:

1. Lower Basin Tribal Conserved Consumptive Use;
2. System Efficiency;
3. System Assessment; and
4. Non-Tribal Conserved Consumptive Use.

It is assumed that when the total conservation volume exceeds the Federally Managed Water Resources Pool capacity, conservation generated through higher-priority contribution mechanisms is

[33] This volume has been proposed to accommodate future water use arrangements, which could include but would not be limited to conservation programs, contracts, and potential Indian water rights settlements.

stored in the Federally Managed Water Resources Pool until it reaches full capacity. Additional details on each mechanism and the associated modeling assumptions are provided in the subsequent sections below.

For all mechanisms, except for water created via System Assessment, it is assumed a one-time system assessment of 10 percent is applied in the year the water is conserved and stored in the Federally Managed Water Resources Pool. Additionally, an annual evaporation deduction of 3 percent is applied in January based on the volume of water remaining in the conservation pool at the end of the preceding calendar year.

Similarly, conversion/delivery from the Federally Managed Water Resources Pool is modeled using the following, prioritized, mechanisms:

1. Federal Tribal Firming
2. Lower Basin Shortage Mitigation
3. Deliveries to benefit LCR MSCP sites

Additional details on the modeling assumptions for the contribution and delivery/conversion of storage credits from the Federally Managed Water Resources Pool are provided below.

B.9.3.3 Contribution

Lower Basin Tribal Conserved Consumptive Use Contribution
For modeling purposes, tribal conserved consumptive use storage credits are assumed to be generated by the CAP Tribes and CRIT-AZ. In CRSS, CAP's entire Colorado River diversion, with the exception of the Salt River Pima-Maricopa Indian Community and Ak-Chin Indian Community portion of the diversion that is Arizona Priority 3, is represented as a single diversion. As such, this diversion is reduced to model the storage credits that are assumed to be generated by CAP Tribes. Such conservation would be voluntary.

For modeling purposes, it is assumed CAP and CRIT-AZ's tribal conserved consumptive use is an initial portion of each water user's contribution volume described in **Section B.9.2.3**, *Contribution*. Specifically**,** given the priority shortage distribution included in the Representative Preferred Alternative, it is assumed CRIT-AZ can create up to 100 kaf per year of tribal conserved consumptive use, and the CAP Tribes can create up to 50 kaf per year of tribal conserved consumptive use.

System Efficiency Contribution
For modeling purposes, it is assumed that voluntary system efficiency projects generate the System Efficiency storage credits. The contribution of this mechanism is phased-in over a three-year period, with 25 kaf in 2027, 50 kaf in 2028, and 75 kaf per year for the remainder of the simulation period (2029-2060). The conservation for this mechanism is modeled by reducing the scheduled demands on the water user that represents the water bypassed pursuant to IBWC Minute 242.

System Assessment Contribution

It is assumed that at the time water is conserved and stored in the Lake Mead mechanism (water user-controlled pools or Federally Managed Water Resources Pool), a one-time three percent system assessment would be applied, along with a one-time seven percent assessment allocated to the Federally Managed Water Resources Pool, for a total assessment of 10 percent. The portion of the assessment allocated to the Federally Managed Water Resources Pool is this "System Assessment Contribution." Water generated via this activity is not subject to a subsequent system assessment. Any assessed volume that cannot be stored in the Federally Managed Water Resources Pool becomes system water.

Non-Tribal Contribution

It is assumed non-tribal contributions are generated when the Lake Mead water user-controlled pools are at capacity, and the respective water users cannot store their full desired annual contribution volume (see **Section B.9.2.2**). Subject to availability in the Federally Managed Water Resources Pool, a maximum of 300 kaf of non-tribal contributions may be stored in the Federally Managed Water Resources Pool annually. Each state's share of the 300 kaf annual contribution limit is assumed to be proportional to the assumed cumulative storage limits modeled for the Lake Mead mechanism and is shown below in **Table B-38**.

Table B-38
Constraints for the Non-Tribal Annual Contributions in the Representative Preferred Alternative

Entity	Maximum Annual Contribution (kaf)
Arizona	42
California	114
Nevada	42
Mexico	102
Total	**300**

B.9.3.4 Delivery/Conversion

Federal Tribal Firming Delivery/Conversion

As noted above, taking delivery/conversion of storage credits from the Federally Managed Water Resources Pool is modeled using three prioritized mechanisms. For modeling purposes, it is assumed the highest priority mechanism is the delivery/conversion of storage credits to meet federal tribal firming obligations.

For modeling purposes only, CAP is assumed to take delivery of storage credits in the Federally Managed Water Resources Pool when shortages exceed specified thresholds as a modeling

approximation of federal tribal firming obligations.[34] The modeled maximum annual delivery/conversion volume relative to these shortage thresholds is provided below in **Table B-39**.

Table B-39
CAP Shortage Thresholds Relative to Delivery/Conversion of Storage Credits in the Representative Preferred Alternative

Current Year Shortage for CAP (kaf)	Maximum Annual Delivery/Conversion Volume (kaf)
≥ 592	36.924
< 592 to ≥ 512	24.325

Lower Basin Shortage Mitigation Delivery/Conversion

Following federal tribal firming, storage credits in the Federally Managed Water Resources Pool are assumed to be delivered/converted to mitigate Lower Basin shortage. For modeling purposes, this delivery/conversion is assumed to occur, subject to availability, when the annual Lower Basin shortage exceeds 1.8 maf for three consecutive years, at which point up to 300 kaf of storage credits in the Federally Managed Water Resources Pool are delivered/converted to mitigate Lower Basin shortage. This shortage mitigation is modeled by reducing the annual Lower Basin shortage volume by a quantity equal to the volume delivered under this mechanism.

LCR MSCP Delivery/Conversion

One of the stated uses of the Federally Managed Water Resources Pool is to provide environmental benefits. As a modeling simplification to represent this in CRSS, storage credits are assumed to be delivered to the Cibola NWR. Cibola NWR was chosen as a modeling simplification and approximation as a representative LCR MSCP site. Subject to available storage credits in the Federally Managed Water Resources Pool, this delivery is modeled as a 40 kaf delivery to the Cibola NWR water user every three years.

[34] Please see the Arizona Water Settlements Act, Pub. L. 108-451, 118 Stat. 3478 (Dec. 10, 2004), section 105, for a general description of the firming program. All firming deliveries in any given year would be made in accordance with applicable law. This appendix is not a legal interpretation of the firming program or of federal obligations. Actual firming deliveries may vary from the modeling approximations contained in this appendix, and Reclamation retains discretion to include legally-required tribal deliveries in this priority mechanism.

B.10 References

Meko, D. M., Woodhouse, C. A., & Touchan, R. (2014). Klamath/San Joaquin/Sacramento Hydroclimatic Reconstructions from Tree Rings, Final Report to California Department of Water Resources, Agreement 4600008850. (California Department of Water Resources, P.O. Box 942836, Sacramento, CA 94236-0001; digital copy of report available at: https://bpb-us-e2.wpmucdn.com/sites.arizona.edu/dist/0/59/files/2024/03/FinalCAWDRreport-5eb3fa6b0a9681d2.pdf
sites/cwoodhouse.faculty.arizona.edu/files/FinalCAWDRreport.pdf

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Appendix C

Shortage Allocation Model and Alternative Distribution Model Documentation

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Attachment

Attachment C-1. Exhibit 5.3.4.1 to the Tohono O'odham Settlement Agreement, *Secretary's Approach for Determining the Amount of Water Available to the Nation During a Time of Shortage Under 1980 Contract*

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 FEIS	2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
2007 ROD	Record of Decision for the adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead
2019 DCP	2019 Lower Basin Drought Contingency Plan
2024 FSEIS	2024 Near-term Colorado River Operations Final Supplemental Environmental Impact Statement
af	acre-feet
afy	acre-feet per year
AWSA	2004 Arizona Water Settlements Act
CAP	Central Arizona Project
CAP Master Repayment Contract	Contract Between the United States and the Central Arizona Water Conservation District for Delivery of Water and Repayment of Costs of the Central Arizona Project, Contract No. 14-06-W-245, as further amended and supplemented
CRBPA	Colorado River Basin Project Act of 1968
CRSS	Colorado River Simulation System
CRWDA	Colorado River Water Delivery Agreement
CU	Consumptive Use
CVWD	Coachella Valley Water District
EIS	Environmental Impact Statement
ICS	intentionally created surplus
Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead
kaf	thousand acre-feet

LMNRA	Lake Mead National Recreation Area
Lower Division States	Arizona, California, and Nevada
M&I	Municipal and Industrial (priority)
maf	million acre-feet
MWD	The Metropolitan Water District of Southern California
NIA	Non-Indian Agricultural (priority)
PABCO	Pacific Coast Building Products, Inc.
PPR	Present Perfected Right
QSA	Quantification Settlement Agreement
Reclamation	Bureau of Reclamation
Secretary	Secretary of the Interior
SNWA	Southern Nevada Water Authority
U.S.	United States

Appendix C. Shortage Allocation Model and Alternative Distribution Model Documentation

This appendix describes the Shortage Allocation Models and Alternative Distribution Models that were used to estimate the results of different concepts or sets of assumptions for the distribution of water during shortages to water users in the States of Arizona, California, and Nevada (Lower Division States) as part of the analysis of alternatives in this Environmental Impact Statement (EIS). Similar material was contained within the following documents:

- Appendix G, Shortage Allocation Model Documentation, to the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead - Final Environmental Impact Statement (2007 FEIS).
- Appendix E, Shortage Allocation Model Documentation, to the 2024 Near-term Colorado River Operations - Final Supplemental Environmental Impact Statement (2024 FSEIS).

C.1 Introduction

To help assess the general effects of changes in the quantity of Colorado River water supplies available to water users in the Lower Division States[1] under alternatives analyzed in this EIS and proposals requested to be evaluated as a sensitivity analysis, the Bureau of Reclamation developed Shortage Allocation Models and Alternative Distribution Models and documented the specific modeling assumptions in this appendix. The results inform analyses described in the Water Deliveries, Socioeconomics, Land Use, and Indian Trust Assets sections of **Chapter 3** of the Final EIS.

C.2 Background and Purpose

The Shortage Allocation Model was created in 2007 to estimate the quantity of Colorado River water that would be available to water entitlement holders or water users under Shortage Conditions on the mainstream lower Colorado River over a specified range of shortage volumes. A Shortage Condition exists during a year when the Secretary of the Department of the Interior (Secretary), as documented in the Annual Operating Plan, determines that there is less than 7.5 million acre-feet (maf) of lower Colorado River water available for consumptive use within the Lower Division States.

[1] The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission in consultation with the Department of State. Total shortage volumes portrayed in Shortage Allocation Models and Alternative Distribution Models include an assumed component for Mexico, as described for each model.

For this EIS, Reclamation further developed what are referred to as Shortage Allocation Models or Alternative Distribution Models. The Shortage Allocation Models and Alternative Distribution Models were developed in parallel with the alternatives development phase of the EIS, in advance of having certainty about formulation of the alternatives and the depths of shortage resulting from their reservoir operating parameters. Stakeholders requested that Reclamation prepare a wide range of models demonstrating the effects of different assumptions for the distribution of water, which could support analyses of alternatives or potential agreements arising among water users in response to reservoir operating guidelines proposed by this EIS.

While this appendix uses the word shortage loosely to mean any modeled reduction to the ability of an entitlement holder[2] to exercise an entitlement as described in the assumptions of the model, reductions arising from voluntary arrangements may not be a Shortage Condition as defined in Article II.B.3 of the Consolidated Decree in *Arizona v. California*, 547 U.S. 150 (2006). The models themselves are not intended to achieve environmental compliance for the depths of shortage the models are capable of calculating, and the models do not themselves imply Federal action at any specific modeled volume; please see **Chapter 3** of the Final EIS for the resource analysis associated with the alternatives. Additionally, these models are not, and are not intended to be, used by Reclamation as implementation tools. The models should only be used for decision support as part of this EIS.

There are eight models documented in this appendix, described briefly in the following paragraphs; the following crosswalk table illustrates the relationship between the alternatives, which are described in **Chapter 2**, and the Shortage Allocation and Alternative Distribution Models.

Table C-1
Crosswalk Between Alternatives and Shortage Allocation and Alternative Distribution Models

Alternative	Shortage Model
Continuing Current Strategies (CCS) Comparative Baseline	CCS Shortage Allocation Model
No Action	Priority Shortage Allocation Model
Representative Preferred (2027-2028)[3]	LB Priority Shortage Allocation Model
Representative Preferred (2029 and later)	Priority Shortage Allocation Model
Basic Coordination	Priority Shortage Allocation Model

[2] Entitlement holders are all persons or entities authorized to beneficially use Colorado River water pursuant to: 1) a right decreed by the United States (U.S) Supreme Court, 2) a contract for the delivery of Colorado River water through the Secretary, or 3) a Secretarial reservation. For a current list of each Lower Division State's Colorado River water entitlement holders, please see: https://www.usbr.gov/lc/region/g4000/contracts/entitlements.html.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See Chapter 2 for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

Alternative	Shortage Model
Enhanced Coordination	Pro Rata Alternative Distribution Model
Maximum Operational Flexibility	LB Priority Shortage Allocation Model
Supply Driven – LB Priority Approach	LB Priority Shortage Allocation Model
Supply Driven – LB Pro Rata Approach	LB Pro Rata Alternative Distribution Model
N/A (Sensitivity)	Priority No Tribal Alternative Distribution Model
N/A (Sensitivity)	Pro Rata No PPR Tribal Alternative Distribution Model
N/A (Sensitivity)	Pro Rata No Tribal Alternative Distribution Model

The Priority Shortage Allocation Model simulates shortage allocations and adjusts deliveries of Colorado River water in accordance with the priority of entitlements within each of the Lower Division States' apportionments.

The Continuing Current Strategies Shortage Allocation Model is an adaptation of the Priority Shortage Allocation Model; it distributes available water first among the Lower Division States based on the 2007 Record of Decision for the adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 ROD) and the 2019 Lower Basin Drought Contingency Plan (2019 DCP) and then among the entitlement holders within each Lower Division State based on priority or as otherwise provided by the 2019 DCP.

The Lower Basin Priority Shortage Allocation Model is an adaptation of the Priority Shortage Allocation Model that uses a different state-level shortage distribution, as specified in the Lower Division States proposal submitted on March 6, 2024.

The other models are referred to as Alternative Distribution Models. These present variations on ways to distribute shortage outside the priority system, which would involve modifications to certain laws, contracts, agreements, and other authorities that are part of the Colorado River legal and contractual framework referred to as Law of the River. The Alternative Distribution Models include distributing shortages in a fully pro rata approach, a pro rata approach using the March 6, 2024, Lower Division States proposed state distribution, variations of the priority and pro rata approaches without shortage to tribes, and a variation of the pro rata approach without shortage to tribal PPR entitlements.

This appendix does not describe possible modifications to Law of the River, as any modifications may be informed by potential agreements arising among water users and would reflect the shortage distribution variation pursued. Certain Shortage Allocation Model and Alternative Distribution Model assumptions analyze distributions of water in ways that diverge from provisions in the Consolidated Decree and other applicable Federal law. Reclamation has determined that, based on public input received during the scoping and alternative development phases of the NEPA process, analysis of these distributions will present a broader range of impacts for agency and stakeholder consideration, review, and input, and will foster meaningful and informed decision-making among Reclamation and Colorado River Basin stakeholders. Such proposals may ultimately not be

implementable. Input from stakeholders on distribution variations, including from Colorado River Basin Tribes, is being identified and considered in the EIS and will help inform any final decision. Reclamation also recognizes that the Supreme Court retains jurisdiction in *Arizona v. California* for the purpose of any order, direction, or modification of the Consolidated Decree, or any supplementary Decree, that may at any time be deemed proper in relation to the subject matter in controversy, or for further amendment or relief. As in the 2001 and 2007 Guidelines, the Secretary anticipates retaining all applicable authority including to respond to emergency conditions in any decision.

Table C-2 presents a comparison of the results of each Shortage Allocation Model and Alternative Distribution Model at certain volumes of total shortage, all in acre-feet per year. The table is presented in three panels, Tribal, Domestic, and Irrigation, consistent with the summary tables for each model that appear at the end of each section of this appendix. Shading indicates the severity of shortage relative to the entitlements associated with each general category of entitlement holder, and is provided for the purpose of enabling a comparison of the effects of different proposals for the distribution of shortage. The following sections explain the assumptions associated with each Shortage Allocation Model and Alternative Distribution Model, which are a combination of universally applied assumptions and those unique to different models.

As described in the following **Section C.3**, model results are presented in this appendix for the levels of total shortage shown on **Table C-2**, all in acre-feet per year, only for the purpose of comparing the effects of the modeled distributions; these volumes were chosen based on points of interest in one or more models, or to provide granularity in the results over a range of volumes of interest. Total shortage volumes include an assumed component for Mexico, as described in the sections of this appendix pertaining to each model, and will not sum across panels.

Table C-2
Heatmap Visualizations for All Shortage Allocation Models and Alternative Distribution Models

Tribal Shortage Impacts	Total Shortage Volume (kaf)										
Modeling Approach	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000	5,000
Priority	241	351	489	550	551	552	555	567	576	585	601
Continuing Current Strategies*	261	305	305	463	463	546	551	563	572	582	601
LB Priority	209	269	346	431	483	510	550	561	571	582	601
Priority w/No Tribal Shortage	0	0	0	0	0	0	0	0	0	0	0
Pro Rata	76	126	189	227	252	264	289	378	441	503	629
LB Pro Rata	139	207	291	324	346	357	380	458	514	569	681
Pro Rata w/No Tribal PPR Shortage	45	75	113	135	150	158	173	225	263	300	376
Pro Rata w/No Tribal Shortage	0	0	0	0	0	0	0	0	0	0	0

Domestic Shortage Impacts	Total Shortage Volume (kaf)										
Modeling Approach	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000	5,000
Priority	277	488	752	876	1,032	1,102	1,224	1,425	1,472	1,518	1,602

Domestic Shortage Impacts	Total Shortage Volume (kaf)										
Continuing Current Strategies*	297	563	563	1,009	1,009	1,171	1,258	1,390	1,446	1,501	1,602
LB Priority	313	579	858	1,024	1,125	1,179	1,263	1,390	1,446	1,501	1,602
Priority w/No Tribal Shortage	492	810	1,157	1,344	1,377	1,387	1,408	1,480	1,532	1,583	1,600
Pro Rata	109	182	273	327	364	382	418	546	637	728	910
LB Pro Rata	155	240	346	397	432	449	483	604	689	775	947
Pro Rata w/No Tribal PPR Shortage	117	195	292	351	390	409	448	585	682	780	975
Pro Rata w/No Tribal Shortage	129	214	321	386	429	450	493	643	750	857	1,071

Irrigation Shortage Impacts	Total Shortage Volume (kaf)										
Modeling Approach	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000	5,000
Priority	6	19	34	44	44	56	98	467	829	1,191	1,924
Continuing Current Strategies*	8	27	46	56	62	65	69	508	859	1,210	1,924
LB Priority	2	9	70	79	85	88	95	509	860	1,211	1,924
Priority w/No Tribal Shortage	23	39	80	143	277	350	496	1,007	1,372	1,737	2,554
Pro Rata	316	526	789	947	1,052	1,105	1,210	1,578	1,841	2,104	2,630
LB Pro Rata	206	387	613	778	889	944	1,054	1,439	1,714	1,989	2,539
Pro Rata w/No Tribal PPR Shortage	338	564	846	1,015	1,127	1,184	1,297	1,691	1,973	2,255	2,819
Pro Rata w/No Tribal Shortage	372	620	929	1,115	1,239	1,301	1,425	1,859	2,168	2,478	3,098

*Continuing Current Strategies results are of limited comparability due to their fixed shortage volumes; shortages shown for 600 kafy and 1.0 mafy in total shortage are associated with 613 kafy and 1,013 kafy of total shortage in the Continuing Current Strategies Shortage Allocation Model.

Notes:

Total shortage volumes include an assumed component for Mexico and will not sum across panels.

The Tribal results panel is shaded on a gradient with zero in white and 1,103.88 kaf in orange. The Domestic results panel is shaded on a gradient with zero in white and 1,606.33 kaf in orange. The Irrigation results panel is shaded on a gradient with zero in white and 4,749.94 kaf in orange. The maximum values are a total of the Consumptive Use or equivalent entitlements assigned to each category.

The color gradient indicates the percentage reduction, with the darkest orange representing 100 percent reduction:

C.3 Assumptions Common to All Shortage Allocation Models and Alternative Distribution Models

Shortage Allocation Models and Alternative Distribution Models are Excel workbooks. Model results are presented in this appendix for the following levels of total shortage, all in acre-feet per year, only for the purpose of comparing the effects of the modeled distributions; these volumes were chosen based on points of interest in one or more models, or to provide granularity in the results over a range of volumes of interest:

- 600,000 (613,000 for the Continuing Current Strategies Shortage Allocation Model)
- 1,000,000 (1,013,000 for the Continuing Current Strategies Shortage Allocation Model)
- 1,500,000
- 1,800,000
- 2,000,000

- 2,100,000
- 2,300,000
- 3,000,000
- 3,500,000
- 4,000,000
- 5,000,000

In all models, volumes of shortage are distributed according to the assumptions of the model without regard to any proposed events causing those volumes of shortage, which are described as part of the alternatives analyzed in this EIS, or the frequency with which certain operational conditions may occur.

For the purpose of consistency with hydrologic modeling results and for comparison across models, total shortage volumes are presented in terms of the Lower Basin as a whole, including Mexico. No opinion on binational negotiations or potential shortages to Mexico under the 1944 Water Treaty or any future minutes is expressed or should be implied, and no attempt is made to further characterize the distribution of shortage within Mexico.

The Shortage Allocation Models and Alternative Distribution Models require certain modeling assumptions with regard to how shortages may be allocated. Reclamation acknowledges there may be other variations of how shortages could be distributed. These modeling assumptions are not intended to represent current or future policy with respect to shortage sharing or to limit Secretarial discretion to distribute shortages. A Shortage Allocation Model or Alternative Distribution Model is not a substitute for the annual process of reviewing water orders and determining annual water availability for each water entitlement holder on the lower Colorado River and, as such, cannot replicate the precision required for that process. While individual entitlement holders may find the results informative, these models are not intended to analyze and do not reflect any entitlement holder's individual drought preparedness or mitigation plans and may thereby overstate impacts.

The Shortage Allocation Models and Alternative Distribution Models developed for this EIS cannot represent the effects of any physical limitations on water access due to low river stage. The models thus assume there are no physical limitations on access to the distributed volume.

Central Arizona Project (CAP) excess water contracts and mainstream unused apportionment or surplus entitlements are subject to availability of water, and under the assumptions of the Shortage Allocation Models and Alternative Distribution Models, water is not available to fulfill them; therefore, they are not itemized in modeling results.

Each state is assumed to be using its entire apportionment each year, and each entitlement holder is assumed to be using its entire entitlement each year. Entitlements are used as the basis for distributing the available water supply to individual users. These assumptions facilitate measuring shortage impacts as a loss of water supply relative to entitlements (estimated or otherwise), or how shortage affects the ability of a water user to exercise an entitlement. The results can be characterized economically as an opportunity cost. Shortage to an entitlement may involve loss of a

wet water supply that is currently in use, loss of a supply currently being used for system conservation or intentionally created surplus (ICS), and/or loss of a future use. For long-range planning, losses to future uses have a cost through foregone opportunities. Accordingly, the Shortage Allocation Models and Alternative Distribution Models do not reflect contractual provisions that provide for unordered water to be made available to other contractors or subcontractors within a priority, or unordered water from one priority to be made available to another. These assumptions are consistent with a reasonably foreseeable long-term steady state for lower Colorado River water use, but in the near term through annual operations, unordered water may be made available to junior priority entitlement holders which would reduce the impacts of shortage.

Shortage to individual entitlements is estimated in terms of consumptive use for a common basis of comparison to state apportionments and volumes of total shortage. Unquantified and diversionary entitlements were estimated in terms of an equivalent consumptive use. Historical water accounting data were used to estimate average consumptive use/diversion ratios as part of development of the Colorado River Simulation System (CRSS) hydrologic modeling dataset for this EIS[4]. For purposes of modeling, these values are assumed to be generally representative of future return flow conditions for the specified users, and are used in the Shortage Allocation Models, Alternative Distribution Models, and CRSS. Those ratios were used to estimate the consumptive use equivalent of diversion entitlements, and the dataset was also used to estimate unquantified entitlements on the basis of maximum recent historical use; these estimates should not be taken as a limit on the future exercise of those entitlements. Shortages quantified in terms of consumptive use may equate to greater reductions on a diversion basis, depending on a user's CU/diversion ratio.

Mechanisms similar to current and/or future paybacks of overruns or underruns under the Inadvertent Overrun and Payback Policy, creation or use of ICS, or storage and interstate release agreements under 43 CFR Part 414 are not modeled.

Individual entitlements are assigned to one of three categories (domestic, irrigation, or tribal) by their primary use or intended benefit, for the purpose of generalizing shortage impacts. No attempt is made to pro-rate shared irrigation and domestic entitlements by actual use. The historical proportions of irrigation and domestic use of these entitlements may change in a Shortage Condition due to contract-specific terms and conditions and/or the discretion of the entitlement holder.

C.3.1 Relationship Between CRSS and the Shortage Allocation Models and Alternative Distribution Models

CRSS was used to model a variety of river and reservoir parameters in the Colorado River Basin, including reservoir elevations and river flows, primarily for use in decision support related to the physical sciences (see **Appendix A**, CRSS Model Documentation). The Shortage Allocation Models and Alternative Distribution Models provide a more detailed allocation of shortages to entitlement

[4] See the section below entitled Relationship Between CRSS and the Shortage Allocation Models and Alternative Distribution Models; where an entitlement is specified by the Consolidated Decree or other authority in terms of both diversion and CU, the Shortage Allocation Models and Alternative Distribution Models use those specified values, regardless of any other historic relationship between diversion and CU for that user.

holders in the Lower Division States, particularly small users and Central Arizona Project (CAP) contractors and subcontractors, for the purpose of decision support related to the social sciences. This section acknowledges known differences between the models that arise from their different modeling platforms, purposes, and assumptions.

A Shortage Allocation Model or Alternative Distribution Model:

- Does not attempt to represent the effect of any physical limitations on access to water due to low river stage
- Does not distinguish between any reasons for reduced deliveries to users (for example by policy, by mutual agreement, or due to operational constraints) but merely emulates an allocation of a shortfall in deliveries from Lake Mead
- Does not account for the creation, delivery, or conversion of ICS
- Has no temporal component and no annual delivery schedules, instead representing a full-use steady state
- Uses most of the same CU equivalent entitlements developed for CRSS, except for the following:
    - CRSS models the Hopi Tribe P4(i) entitlement as fully consumptive by 2040, while the Shortage Allocation Models and Alternative Distribution Models retain the initial assumption of a 3,037 af consumptive use equivalent entitlement based on a CU/diversion ratio of 0.71.
    - Unallocated P4(i) water is shown as 9,870 af in CRSS and 10,230 af in the Shortage Allocation Models and Alternative Distribution Models.
    - Town of Queen Creek's 2,033.01 af entitlement is identified by name in the Shortage Allocation Models and Alternative Distribution Models, while CRSS models it as part of the CAP diversion.
    - For Imperial and Havasu National Wildlife Refuges, the Shortage Allocation Models and Alternative Distribution Models use the decreed CU entitlements, while CRSS uses a constrained CU based on past water accounting data.
    - The California P2 entitlement for Bard Water District is shown as 7,294 af in the Shortage Allocation Models and Alternative Distribution Models versus 2,294 af in CRSS, where demand was adjusted by 5.0 kaf to represent the effect of the Bard seasonal fallowing program.
    - The Shortage Allocation Models and Alternative Distribution Models reflect the decreed CU entitlement for the Lake Mead National Recreation Area PPR of 300 af, while CRSS assumes full consumption of the decreed diversionary entitlement of 500 af.
- Distributes water by priority similarly to CRSS, except for the following:
    - In the Arizona P4(i) pool, the priority-based Shortage Allocation Models and Alternative Distribution Models distribute shortage in proportion to entitlements, which are quantified on a diversion basis. CRSS distributes shortage in proportion to the CU equivalent of the entitlements, resulting in slightly different ratios between the models.

- An Arizona entitlement in the name of Desert Lawn, for 248.40 afy, is modeled in the P4(i) pool in CRSS and the P3 pool in the Shortage Allocation Models and Alternative Distribution Models. Its priority and status were being re-evaluated at the time modeling assumptions were developed.
- Arizona P2 and P3 are modeled as co-equal in the Shortage Allocation Models and Alternative Distribution Models, while CRSS fills them sequentially.
- California P3a and P3b are modeled as co-equal in the Shortage Allocation Models and Alternative Distribution Models, while CRSS first reduces P3b before shortage is applied to P3a.
- Comments received on California's modeled P4 demands in CRSS for the Draft EIS identified an inconsistency in modeling assumptions for P3 use. Please see **Appendix M** - Lower Division State Depletion Schedules.
- CRSS models California's Quantification Settlement Agreements (QSA) related transfers as demand for the receiving entity (for example as use by The Metropolitan Water District of Southern California [MWD]) while maintaining the priority of the water in priority-based model runs. As described for the Priority Shortage Allocation Model, QSA transfers and exchanges were not modeled independent of the underlying entitlements in the Shortage Allocation Models or Alternative Distribution Models.
- The Shortage Allocation Models and Alternative Distribution Models treat Nevada's P8 "Balance and Surplus" as a separate priority category that is reduced to zero before Laughlin and the quantified Robert B. Griffith Project P8 allocations are shorted, and reduces P8 in full before shortage begins to P7. CRSS sets all Nevada P8 use as co-equal, and models P3, P4, P5, and P6 with P8.
- The Shortage Allocation Models' and Alternative Distribution Models' PPR fill order shorts each PPR entitlement individually and sequentially, according to an assumed fill order, while CRSS models similarly-situated PPR entitlements together.
- Minor differences in shortage attributed to Mexico result from different applications of rounding.

Table C-3 and **Table C-4** below present a comparison of results between the Priority Shortage Allocation Model and CRSS, and the Pro Rata Alternative Distribution Model and CRSS, at the 1.5 mafy volume of shortage. The CRSS results are taken from the 2040 timestep where full-use assumptions are most comparable to the Shortage Allocation Models and Alternative Distribution Models.

Table C-3
Comparison of Shortage Volume Results Between CRSS in 2040 and the Priority Shortage Allocation Model at the 1.5 mafy Volume of Shortage

User	Shortage Allocation Model Results (afy)	CRSS Results (afy)	Difference (Shortage Allocation Model – CRSS) (afy)
Mexico	250,000	250,050	-50
Nevada	88,982	82,820	6,161
8th Priority (Southern Nevada Water Authority [SNWA] & Big Bend)	88,982	82,820	6,161
7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	0	0	0
6th Priority (Las Vegas Valley Water District)	0	Modeled in 8th Priority	Modeled in 8th Priority
5th Priority (PABCO)	0	Modeled in 8th Priority	Modeled in 8th Priority
4th Priority (Henderson & Basic)	0	Modeled in 8th Priority	Modeled in 8th Priority
3rd Priority (Boulder City)	0	Modeled in 8th Priority	Modeled in 8th Priority
2nd Priority (Lake Mead National Rec Area)	0	0	0
1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	0	0	0
California	0	0	0
4th Priority (MWD)	0	0	0
3rd Priority (IID, Coachella Valley Water District [CVWD], PVID)	0	0	0
2nd Priority (Yuma Project Reservation Division)	0	0	0
1st Priority (PVID)	0	0	0
Present Perfected Rights (PPRs)	0	0	0
Arizona	1,161,018	1,167,130	-6,112
4th Priority	1,161,018	1,167,130	-6,112
2nd and 3rd Priorities	0	0	0
1st Priority (Present Perfected Rights)	0	0	0

Table C-4
Comparison of Shortage Volume Results Between CRSS in 2040 and the Pro Rata Alternative Distribution Model at the 1.5 mafy Volume of Shortage

User	Shortage Allocation Model Results (afy)	CRSS Results (afy)	Difference (Shortage Allocation Model – CRSS) (afy)
Mexico	249,365	250,000	-635
Nevada	49,873	50,000	-127
8th Priority (SNWA & Big Bend)	42,508	48,263	-460
7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	375	4	371
6th Priority (Las Vegas Valley Water District)	1,332	Modeled in 8th Priority	Modeled in 8th Priority
5th Priority (PABCO)	80	Modeled in 8th Priority	Modeled in 8th Priority
4th Priority (Henderson & Basic)	3,375	Modeled in 8th Priority	Modeled in 8th Priority
3rd Priority (Boulder City)	508	Modeled in 8th Priority	Modeled in 8th Priority
2nd Priority (Lake Mead National Rec Area)	249	250	-1
1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	1,446	1,483	-37
California	731,471	733,333	-1,862
4th Priority (MWD)	64,503	50,450	14,053
3rd Priority (IID, CVWD, PVID)	138,813	155,917	-17,103
2nd Priority (Yuma Project Reservation Division)	1,213	382	830
1st Priority (PVID)	61,240	61,396	-156
Present Perfected Rights (PPRs)	465,702	465,188	514
Arizona	469,290	466,666	2,624
4th Priority	237,236	240,430	-3,194
2nd and 3rd Priorities	132,672	126,623	6,049
1st Priority (Present Perfected Rights)	99,382	99,613	-230

C.4 Priority Shortage Allocation Model Assumptions

The Priority Shortage Allocation Model, similar to the Shortage Allocation Model developed for the 2007 FEIS, represents an interpretation of the lower Colorado River priority systems among and within the Lower Division States. As discussed in this section, the Priority Shortage Allocation Model, given a volume of total shortage to the Lower Basin, distributes available water first among the states, and subsequently within each state among the entitlement holders based on priority.

For each level of modeled shortage, the Priority Shortage Allocation Model calculates a percentage reduction to the Lower Division States and applies the same percentage reduction to Mexico's 1,500,000 acre-feet per year allotment.

The Excel workbook contains formulas extending into deep shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS and is included for informational purposes.

C.4.1 Present Perfected Rights Assumptions for the Priority Shortage Allocation Model

Present Perfected Rights (PPRs), defined to mean perfected rights existing as of June 25, 1929, the effective date of the Boulder Canyon Project Act (see Article I.(H) of the Consolidated Decree in *Arizona v. California*, 547 U.S. 150 (2006)), are an integral part of the priority system in the lower Colorado River Basin.

Article III(a) of the Colorado River Compact of 1922 provides, quoted in pertinent part to PPRs: "There is hereby apportioned from the Colorado River System in perpetuity to… the Lower Basin… 7,500,000 acre feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist." Article VIII further provides that "Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact." Section 6 of the Boulder Canyon Project Act also provides that: "the dam and reservoir . . . shall be used: . . . second, for irrigation and domestic uses and satisfaction of present perfected rights in pursuance of Article VIII of said Colorado River compact."

After enumerating and quantifying the PPRs through the *Arizona v. California* litigation (see, e.g., 439 U.S. 419 (1979)), the Supreme Court provides in the Consolidated Decree in *Arizona v. California*, Article II, "The United States, its officers, attorneys, agents and employees be and they are hereby severally enjoined:…

> (B) From releasing water controlled by the United States for irrigation and domestic use in the States of Arizona, California, and Nevada, except as follows:…
>
> (3) If insufficient mainstream water is available for release, as determined by the Secretary of the Interior, to satisfy annual consumptive use of 7,500,000 acre-feet in the aforesaid three States, then the Secretary of the Interior, after providing for satisfaction of present perfected rights in the order of their priority dates without regard to state lines and after consultation with the parties to major delivery contracts and such representatives as the respective States may designate, may apportion the amount remaining available for consumptive use in such manner as is consistent with the Boulder Canyon Project Act as interpreted by the opinion of this Court herein, and with other applicable federal statutes…" (Emphasis added.)

Additionally, Article III of the Consolidated Decree provides that:

> "III. The States of Arizona, California, and Nevada, Palo Verde Irrigation District, Imperial Irrigation District, Coachella Valley Water District, the Metropolitan Water District of Southern California, City of Los Angeles, City of San Diego, and County of San Diego, and all other users of water from the mainstream in said States, their officers, attorneys, agents, and employees, be and they are hereby severally enjoined:…
>
> (B) From interfering with or purporting to authorize the interference with releases and deliveries, in conformity with Article II of this decree, of water controlled by the United States;"

Finally, Paragraph (5) of the Appendix to the Consolidated Decree provides:

> "In the event of a determination of insufficient mainstream water to satisfy present perfected rights pursuant to Article II(B)(3) of this decree, the Secretary of the Interior shall, before providing for the satisfaction of any of the other present perfected rights except for those listed herein as "MISCELLANEOUS PRESENT PERFECTED RIGHTS" (rights numbered 7–21 and 29–80 below) in the order of their priority dates without regard to state lines, first provide for the satisfaction in full of all rights of the Chemehuevi Indian Reservation, Cocopah Indian Reservation, Fort Yuma Indian Reservation, Colorado River Indian Reservation, and the Fort Mojave Indian Reservation as set forth in Article II(D)(1)–(5) of this decree...."

In the Priority Shortage Allocation Model, PPRs are satisfied according to the assumed fill order provided on the following page in **Table C-5** (bottom up), derived from Paragraph 5 of the Appendix to the Consolidated Decree. In order to model this fill order and other elements of the priority system, the Priority Shortage Allocation Model distinguishes PPRs from other priorities of water held by a single entitlement holder. PPRs are assumed to be fully filled before any post-PPR entitlements receive water. Individual PPRs are enumerated in summary tables alongside other entitlements.

The documents cited in this section also underlie the modeled relationship between PPRs and the state-level distribution of shortage (which is further discussed in the next section).

Table C-5
Present Perfected Right Summary and Assumed Fill Order

Entitlements

Arizona, California, and Nevada Summary	CU Equivalent (af)	Diversion (af)
Arizona Total	597,811	1,077,971
California Total	2,801,326	3,019,573
Nevada Total	8,698	13,034
Total	3,407,835	4,110,578

Entitlement Holders	CU Equivalent (af)	Diversion (af)	PPR No.	Date	State	Category	Cumulative Consumptive Use Equivalent (af)
Lake Mead National Recreation Area (Overton Area, EO 5105)	300	500	82	1929	NV	Federal Establishments & Water Projects	3,407,835
Molina	318†	318	15	1928	AZ	Miscellaneous	3,407,535
Sonny Gowan (Grannis)	115†	180	32	1928	CA	Miscellaneous	3,407,217
Diehl	0.6	1	59	1928	CA	Miscellaneous	3,407,102
Stallard	0.6	1	66	1928	CA	Miscellaneous	3,407,101
Estrada	0.6	1	77	1928	CA	Miscellaneous	3,407,101
Corrington	0.6	1	79	1928	CA	Miscellaneous	3,407,100
Tolliver	0.6	1	80	1928	CA	Miscellaneous	3,407,100
Randolph	0.6	1	65	1926	CA	Miscellaneous	3,407,099
Keefe	0.6	1	67	1926	CA	Miscellaneous	3,407,098
Sturges (Gila Monster Farms, Inc.)	445†	780	16	1925	AZ	Miscellaneous	3,407,098
Chagnon	77†	120	41	1925	CA	Miscellaneous	3,406,653
Faubion	0.6	1	48	1925	CA	Miscellaneous	3,406,576
Earle	0.6	1	58	1925	CA	Miscellaneous	3,406,576
Whittle	0.6	1	78	1925	CA	Miscellaneous	3,406,575
Beauchamp	0.6	1	51	1924	CA	Miscellaneous	3,406,575
McGee	0.6	1	63	1924	CA	Miscellaneous	3,406,574
Stallard	0.6	1	64	1924	CA	Miscellaneous	3,406,573
Hadlock	0.6	1	72	1924	CA	Miscellaneous	3,406,573
Stephenson	154†	240	30	1923	CA	Miscellaneous	3,406,572
Draper, G.	0.6	1	46	1923	CA	Miscellaneous	3,406,419
Dudley	0.6	1	49	1922	CA	Miscellaneous	3,406,418
Colorado River Sportsmen's League	61†	96	36	1921	CA	Miscellaneous	3,406,417
Andrade	42†	66	38	1921	CA	Miscellaneous	3,406,356
Conger	0.6	1	45	1921	CA	Miscellaneous	3,406,314
Vaulin	0.6	1	70	1920	CA	Miscellaneous	3,406,313
Salisbury	0.6	1	71	1920	CA	Miscellaneous	3,406,313
McDonough	0.6	1	47	1919	CA	Miscellaneous	3,406,312
Cate	0.6	1	62	1919	CA	Miscellaneous	3,406,311
Milpitas	69†	108	34	1918	CA	Miscellaneous	3,406,311
Yuma Auxiliary Project, Unit B	4,352†	6,800	5	1905	AZ	Federal Establishments & Water Projects	3,406,242
North Gila Valley Unit, Yuma Mesa Division, Gila Project	6,125†	24,500	6	1905	AZ	Federal Establishments & Water Projects	3,401,890

Entitlement Holders	CU Equivalent (af)	Diversion (af)	PPR No.	Date	State	Category	Cumulative Consumptive Use Equivalent (af)
Reservation Division/Yuma Project (non-Indian portion)	19,518[†]	38,270	28	1905	CA	Federal Establishments & Water Projects	3,395,765
Valley Division, Yuma Project (Yuma County Water Users' Association)	170,314[†]	254,200	4	1901	AZ	Federal Establishments & Water Projects	3,376,247
Imperial Irrigation District & CVWD lands	2,600,000[†]	2,600,000	27	1901	CA	Federal Establishments & Water Projects	3,205,933
Palo Verde Irrigation District	94,505[†]	219,780	26	1877	CA	Federal Establishments & Water Projects	605,933
Cocopah Indian Reservation	5,146[†]	7,681	1	1917	AZ	Indian Reservations	511,428
Schneider	0.6	1	56	1917	CA	Miscellaneous	506,281
Douglas	0.6	1	50	1916	CA	Miscellaneous	506,281
Clark	0.6	1	52	1916	CA	Miscellaneous	506,280
Graham	0.6	1	61	1916	CA	Miscellaneous	506,279
Powers	624[†]	960	7	1915	AZ	Miscellaneous	506,279
United States (Cocopah Indian Tribe)	764[†]	1,140	8	1915	AZ	Miscellaneous	505,655
Lawrence	77[†]	120	42	1915	CA	Miscellaneous	504,891
Lawrence	0.6	1	53	1915	CA	Miscellaneous	504,814
Milpitas	44[†]	69	37	1914	CA	Miscellaneous	504,814
Graham, J.	0.6	1	54	1914	CA	Miscellaneous	504,770
Morgan	96[†]	150	33	1913	CA	Miscellaneous	504,769
Zozaya (MVIDD)	389[†]	720	17	1912	AZ	Miscellaneous	504,673
Reid	0.6	1	60	1912	CA	Miscellaneous	504,284
Fitz	0.6	1	75	1912	CA	Miscellaneous	504,284
EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	238[†]	360	9	1910	AZ	Miscellaneous	504,283
Geiger	0.6	1	55	1910	CA	Miscellaneous	504,045
Williams	0.6	1	76	1909	CA	Miscellaneous	504,045
Chemehuevi Indian Reservation	6,124[†]	11,340	22	1907	CA	Indian Reservations	504,044
Parker, City of	400	630	20	1905	AZ	Miscellaneous	497,921
Cooper	38[†]	60	40	1905	CA	Miscellaneous	497,521
Reynolds	23[†]	36	39	1904	CA	Miscellaneous	497,482
Ferguson, C.	0.6	1	68	1903	CA	Miscellaneous	497,459
Ferguson, W.	0.6	1	69	1903	CA	Miscellaneous	497,458
Streeter	0.6	1	73	1903	CA	Miscellaneous	497,458
Draper, J.	0.6	1	74	1903	CA	Miscellaneous	497,457
Hulet (MVIDD)	583[†]	1,080	10	1902	AZ	Miscellaneous	497,457
Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	567[†]	1,050	11	1902	AZ	Miscellaneous	496,873
Miller (MVIDD)	130[†]	240	12	1902	AZ	Miscellaneous	496,306
McKellips and Granite Reef Farms (MVIDD)	437[†]	810	13	1902	AZ	Miscellaneous	496,177
Sherrill & Lafollette (MVIDD)	583[†]	1,080	14	1902	AZ	Miscellaneous	495,739
Swan (MVIDD)	518[†]	960	18	1902	AZ	Miscellaneous	495,156
Phillips, Milton and Jean	42[†]	42	19	1900	AZ	Miscellaneous	494,638
City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	273[†]	1,260	44	1896	CA	Miscellaneous	494,596
Martinez	0.6	1	57	1895	CA	Miscellaneous	494,323
Yuma, City of	1,478	2,333	21	1893	AZ	Miscellaneous	494,322
Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	77[†]	120	31	1893	CA	Miscellaneous	492,844
Fort Mojave Indian Reservation	40,806[†]	75,566	3	1890	AZ	Indian Reservations	492,767
Fort Mojave Indian Reservation	15,103[†]	27,969	3	1890	AZ	Indian Reservations	451,962
Fort Mojave Indian Reservation	9,029[†]	16,720	25	1890	CA	Indian Reservations	436,859

Entitlement Holders	CU Equivalent (af)	Diversion (af)	PPR No.	Date	State	Category	Cumulative Consumptive Use Equivalent (af)
Fort Mojave Indian Reservation	8,398[†]	12,534	81	1890	NV	Indian Reservations	427,830
Simons	38[†]	60	35	1889	CA	Miscellaneous	419,432
City of Needles	950	1,500	43	1885	CA	Miscellaneous	419,394
Fort Yuma Indian Reservation	36,524[†]	71,616	23	1884	CA	Indian Reservations	418,444
Fort Yuma Indian Reservation	4,001[†]	6,350	3a	1884	AZ	Indian Reservations	381,919
Colorado River Indian Reservation	3,399[†]	5,860	24	1876	CA	Indian Reservations	377,919
Colorado River Indian Reservation	27,033[†]	51,986	2	1874	AZ	Indian Reservations	374,520
Colorado River Indian Reservation	23,340[†]	40,241	24	1874	CA	Indian Reservations	347,487
Colorado River Indian Reservation	131,048[†]	252,016	2	1873	AZ	Indian Reservations	324,148
Colorado River Indian Reservation	6,232[†]	10,745	24	1873	CA	Indian Reservations	193,099
Colorado River Indian Reservation	186,368[†]	358,400	2	1865	AZ	Indian Reservations	186,867
Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	499[†]	780	29	1856	CA	Miscellaneous	499
Total	**3,407,835**	**4,110,578**					

[†]Calculated consumptive use equivalent. Historical Decree Accounting data were used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS. For purposes of modeling, these values are assumed to be generally representative of return flow conditions for the specified users, and match CRSS inputs. Those ratios were used to estimate the consumptive use equivalent of diversion entitlements. In CA, miscellaneous PPRs were assumed to have a CU/Div ratio of .64. For IID, consumptive use was assumed to equal diversion since the CU/diversion ratio based on average historical efficiency was 0.996. In AZ, with limited supporting data about miscellaneous PPRs, they were assumed to be fully consumptive. Where an entitlement was quantified on the basis of CU by the Consolidated Decree, those values are used. The Cumulative Consumptive Use Equivalent column is included as a reference for the estimated amount of water that would need to be available to PPRs to fulfill a given entitlement on this table.

C.4.2 Distribution Among States for the Priority Shortage Allocation Model

With regard to distribution of available water among the Lower Division States, the Priority Shortage Allocation Model assumes their apportionments[5] as coequal, with exceptions relating to PPRs and to the Colorado River Basin Project Act of 1968 (CRBPA).

First, with respect to PPRs, the 1963 Opinion in *Arizona v. California*, 373 U.S. 546, 592-93 in Article III. Apportionment and Contracts in Time of Shortage, provides, in part:

> "There remains the question of what shall be done in time of shortage. The Master, while declining to make any findings as to what future supply might be expected, nevertheless decided that the Project Act and the Secretary's contracts require the Secretary in case of shortage to divide the burden among the three States in this proportion: California 4.4/7.5; Arizona 2.8/7.5; Nevada .3/7.5. While pro rata sharing of water shortages seems equitable on its face, [] more considered judgment may demonstrate quite the contrary. Certainly we should not bind the Secretary to this formula. We have held that the Secretary is vested with considerable control over the apportionment of Colorado River waters. And neither the Project Act nor the water contracts require the use of any particular formula for apportioning shortages. While the Secretary must follow the standards set out in the Act, he nevertheless is free to choose among the recognized methods of apportionment or to devise reasonable methods of his own. This choice, as we see it, is primarily his, not the Master's or even ours. And the Secretary may or may not conclude that a pro rata division is the best solution. . . ." (Footnote omitted.)
>
> None of this is to say that in case of shortage, the Secretary cannot adopt a method of proration or that he may not lay stress upon priority of use, local laws and customs, or any other factors that might be helpful in reaching an informed judgment in harmony with the Act, the best interests of the Basin States, and the welfare of the Nation. It will be time enough for the courts to intervene when and if the Secretary, in making apportionments or contracts, deviates from the standards Congress has set for him to follow, including his obligation to respect "present perfected rights" as of the date the Act was passed. . . . Finally, as the Master pointed out, Congress still has broad powers over this navigable international stream. Congress can undoubtedly reduce or enlarge the Secretary's power if it wishes. Unless and until it does, we leave in the hands of the Secretary, where Congress placed it, full power to control, manage, and operate the Government's Colorado River works and to make contracts for the sale and delivery of water on such terms as are not prohibited by the Project Act."

Consistent with the 1963 Opinion and Article II(B)(3) of the Consolidated Decree, the state distribution for the Priority Shortage Allocation Model provides first for the satisfaction of PPRs in full, before apportioning the amount remaining available for consumptive use among the Lower

[5] 2,800,000 afy to Arizona, 4,400,000 afy to California, and 300,000 afy to Nevada on a consumptive use basis. See Section 4 of the Boulder Canyon Project Act and Article II(B) of the Consolidated Decree in Arizona v. California.

Division States. The ratios used for that apportionment are further described in the following **Section C.4.2.1**, Stage 1 and 2 Shortage Assumptions.

Second, with respect to the CRBPA, Section 301(b) provides, in part:

> "in any year in which, as determined by the Secretary, there is insufficient main stream Colorado River water available for release to satisfy annual consumptive use of seven million five hundred thousand acre-feet in Arizona, California, and Nevada, diversions from the main stream for the Central Arizona Project shall be so limited as to assure the availability of water in quantities sufficient to provide for the aggregate annual consumptive use by holders of present perfected rights, by other users in the State of California served under existing contracts with the United States by diversion works heretofore constructed, and by other existing Federal reservations in that State, of four million four hundred thousand acre-feet of mainstream water, and by users of the same character in Arizona and Nevada. Water users in the State of Nevada shall not be required to bear shortages in any proportion greater than would have been imposed in the absence of this subsection 301(b)."

Additionally, the language of the Arizona priority system as contained in the CAP "Master Repayment Contract"[6] and other Arizona fourth priority Colorado River water delivery contracts provides that CAP and other post-1968 fourth priority contracts in Arizona are coequal in priority. For the purpose of the Priority Shortage Allocation Model, these provisions are assumed to reduce CAP and other Arizona fourth priority Colorado River water uses completely before water available to California is reduced below 4,400,000 acre-feet per year (afy). Mathematically, modeled shortage to Nevada is unaffected by assumptions relating to Section 301(b) of the CRBPA.

The formulation of ratios associated with these assumptions is further described in the subsection immediately below.

C.4.2.1 Stage 1 and 2 Shortage Assumptions

As in the Shortage Allocation Models for the 2007 FEIS and the 2024 FSEIS, the initial shortages to the Lower Division States in this Priority Shortage Allocation Model are characterized by two stages, Stage 1 and Stage 2. In Stage 1, shortages are imposed only upon Arizona and Nevada, continuing until the deliveries to the post-1968 water entitlement holders in Arizona (including the CAP) are reduced to zero. The maximum amount of Stage 1 shortage during the period of analysis is dependent on estimated water availability for the post-1968 water entitlement holders in Arizona.[7]

[6] Contract Between the U.S. and the Central Arizona Water Conservation District for Delivery of Water and Repayment of Costs of the Central Arizona Project, Contract No. 14-06-W-245, Amendment No. 1, dated December 1, 1988, as further amended and supplemented.

[7] The breakpoint between Stage 1 and Stage 2, when California begins to share in shortage, is a precise point at which no Arizona fourth priority Colorado River water is available. In the short run, this breakpoint is non-stationary and varies annually based on use by Arizona priorities one through three. For the Priority Shortage Allocation Model, a shortage volume of 1,404,130 af to the State of Arizona is used as the volume that reduces Arizona fourth priority Colorado River water availability to zero, based on assumed full use of Arizona priority one through three entitlements. The total volume of Stage 1 shortage is dependent on this assumption, as are the state ratios for distribution of Stage 2 shortage.

Stage 1 shortage in this Priority Shortage Allocation Model is consistent with the guiding documents cited in the previous subsections, but the ratios differ from those used in the 2007 FEIS and the 2024 FSEIS because those Shortage Allocation Models deliberately aligned with policy alternatives that did not consider shortages large enough to impact PPRs. At deeper shortages to the Lower Basin, such as 5.0 maf, the distribution of water among the Lower Division States using an unmodified extension of the 2007 methodology (distributing shortage in proportion to state apportionments) could create inconsistencies with obligations cited in **Section C.3.1** above because it may not provide sufficient water to fill all PPRs in every state, resulting in a mix of shortages to PPR entitlements and water available to non-PPR entitlements.[8]

The approach employed in the Priority Shortage Allocation Model for distributing shortage among the Lower Division States ensures that PPRs can be satisfied (or reduced) in the prescribed order as a Basin-wide senior priority group. Instead of setting the entire volume of each state's apportionment as coequal to the others, only state apportionments in excess of PPRs are treated as coequal (but maintaining the assumption that Arizona bears California's share of shortage until the Arizona fourth priority is exhausted). In developing the Stage 1 and Stage 2 percentages for the sharing of shortage among the Lower Division States, the consumptive use (or equivalent) of PPR entitlements was removed from each state's apportionment volumes, as detailed below. The Stage 2 distribution of water among the Lower Division States ends at the volume of total shortage where reductions to PPRs are necessary and all non-PPR entitlements have been fully reduced in each state; at that point, water available to each state equals the consumptive use (or equivalent) of PPR entitlements within the state. The distribution of water among PPRs is characterized as a Stage 3, where water available to each state is an aggregation of the PPR volumes within the state that could be filled at a given level of shortage.

The Stage 1 shortage sharing percentages for the Priority Shortage Allocation Model are computed as follows[9]:

- Nevada bears a reduction of about 7 percent of the total Lower Division States shortage volume, computed as a ratio of Nevada's apportionment less PPR consumptive use (or equivalent) entitlements within Nevada over the sum of the apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements
    - (0.3 maf – NV PPRs) / (7.5 maf -total PPRs) = 7.12 percent, or
        - (0.3 maf – 8,698 af) / (7.5 maf – 3,407,835 af) = 7.12 percent
- Arizona bears the remainder of the total Lower Division States shortage volume (approximately 93 percent), computed as a ratio of Arizona's and California's apportionments less PPR consumptive use (or equivalent) in both states over the sum of the

[8] See pages 306 through 312 of Special Master Simon Rifkind's 1960 Report to the Supreme Court in *Arizona v. California*, 364 U.S. 940 (1961), where the Special Master reaches the same conclusion and describes another potential methodology for responding to it.
[9] Note that these ratios distribute shortage volumes, and the available water is calculated as a remainder.

apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements

- (2.8 maf – AZ PPRs + 4.4 maf – CA PPRs) / (7.5 maf – total PPRs) = 92.88 percent, or
    - (2.8 maf – 597,811 af + 4.4 maf – 2,801,326 af) / (7.5 maf – 3,407,835 af) = 92.88 percent

As in the original Shortage Allocation Model, after deliveries to the fourth priority entitlements within Arizona are expected to be reduced to zero, any additional shortage is shared among Arizona, California, and Nevada. This additional shortage is Stage 2 and is in addition to the Stage 1 shortage volume; the Stage 2 shortage is distributed according to the Stage 2 ratios.

The Stage 2 shortage sharing percentages are computed as follows, with the PPR volumes the same as in the Stage 1 ratios.

- Nevada bears about 7 percent of the Stage 2 shortage in addition to its Stage 1 shortage, computed as a ratio of Nevada's apportionment less PPRs less the amount of shortage applied to Nevada under Stage 1, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1
    - (0.3 maf – NV PPRs – Nevada Stage 1 shortage) / (7.5 maf – total PPRs – total Stage 1 shortage) = 7.12 percent, or
        - (300,000 - 8,698 - 107,540) / (7,500,000 - 3,407,835 - 1,511,744) = 7.12 percent
- Arizona bears about 31 percent of the Stage 2 shortage in addition to its Stage 1 shortage, computed as a ratio of Arizona's apportionment less PPRs less the amount of shortage applied to Arizona under Stage 1, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1
    - (2.8 maf – AZ PPRs – Arizona Stage 1 shortage) / (7.5 maf – total PPRs – total Stage 1 shortage) = 30.93 percent, or
        - (2,800,000 - 597,811 - 1,404,130) / (7,500,000 - 3,407,835 - 1,511,744) = 30.93 percent
- California bears about 62 percent of the Stage 2 shortage, computed as a ratio of California's apportionment less PPRs, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1
    - (4.4 maf – CA PPRs) / (7.5 maf – total PPRs – total Stage 1 shortage) = 61.95 percent, or
        - (4,400,000 - 2,801,326) / (7,500,000 - 3,407,835 - 1,511,744) = 61.95 percent

This method represents one possible way to distribute deep shortages among the Lower Division States in a way that does not reduce PPR water deliveries in one state while fulfilling non-PPR water deliveries in another state. Below Stage 2, water available to each state is calculated as the sum of the PPR volumes within the state that could be filled at a given level of shortage.

Table C-6 below summarizes the distribution of shortage and available water to the Lower Division States under the Priority Shortage Allocation Model. Total shortage volumes include an assumed component for Mexico, as described in the sections that follow, and will not sum across rows.

Table C-6
Summary of Shortage Volumes and Available Water by Lower Division State Under the Priority Shortage Allocation Model (af)

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
0	0	2,800,000	0	4,400,000	0	300,000
(10,000)	(7,740)	2,792,260	0	4,400,000	(593)	299,407
(40,000)	(30,960)	2,769,040	0	4,400,000	(2,373)	297,627
(50,000)	(38,701)	2,761,299	0	4,400,000	(2,966)	297,034
(70,000)	(54,181)	2,745,819	0	4,400,000	(4,152)	295,848
(100,000)	(77,401)	2,722,599	0	4,400,000	(5,932)	294,068
(120,000)	(92,881)	2,707,119	0	4,400,000	(7,119)	292,881
(140,000)	(108,362)	2,691,638	0	4,400,000	(8,305)	291,695
(200,000)	(154,802)	2,645,198	0	4,400,000	(11,864)	288,136
(240,000)	(185,763)	2,614,237	0	4,400,000	(14,237)	285,763
(360,000)	(278,644)	2,521,356	0	4,400,000	(21,356)	278,644
(399,600)	(309,295)	2,490,705	0	4,400,000	(23,705)	276,295
(400,000)	(309,605)	2,490,395	0	4,400,000	(23,728)	276,272
(480,000)	(371,526)	2,428,474	0	4,400,000	(28,474)	271,526
(500,400)	(387,316)	2,412,684	0	4,400,000	(29,684)	270,316
(600,000)	(464,407)	2,335,593	0	4,400,000	(35,593)	264,407
(720,000)	(557,289)	2,242,711	0	4,400,000	(42,711)	257,289
(700,000)	(541,809)	2,258,191	0	4,400,000	(41,525)	258,475
(800,000)	(619,210)	2,180,790	0	4,400,000	(47,457)	252,543
(840,000)	(650,170)	2,149,830	0	4,400,000	(49,830)	250,170
(900,000)	(696,611)	2,103,389	0	4,400,000	(53,389)	246,611
(960,000)	(743,052)	2,056,948	0	4,400,000	(56,948)	243,052
(1,000,000)	(774,012)	2,025,988	0	4,400,000	(59,321)	240,679
(1,075,000)	(832,063)	1,967,937	0	4,400,000	(63,770)	236,230
(1,080,000)	(835,933)	1,964,067	0	4,400,000	(64,067)	235,933
(1,090,000)	(843,673)	1,956,327	0	4,400,000	(64,660)	235,340
(1,100,000)	(851,413)	1,948,587	0	4,400,000	(65,253)	234,747
(1,200,000)	(928,815)	1,871,185	0	4,400,000	(71,185)	228,815

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(1,320,000)	(1,021,696)	1,778,304	0	4,400,000	(78,304)	221,696
(1,365,000)	(1,056,527)	1,743,473	0	4,400,000	(80,973)	219,027
(1,440,000)	(1,114,578)	1,685,422	0	4,400,000	(85,422)	214,578
(1,480,000)	(1,145,538)	1,654,462	0	4,400,000	(87,795)	212,205
(1,490,000)	(1,153,278)	1,646,722	0	4,400,000	(88,388)	211,612
(1,500,000)	(1,161,018)	1,638,982	0	4,400,000	(88,982)	211,018
(1,560,000)	(1,207,459)	1,592,541	0	4,400,000	(92,541)	207,459
(1,600,000)	(1,238,420)	1,561,580	0	4,400,000	(94,914)	205,086
(1,680,000)	(1,300,340)	1,499,660	0	4,400,000	(99,660)	200,340
(1,800,000)	(1,393,222)	1,406,778	0	4,400,000	(106,778)	193,222
(1,814,093)	(1,404,130)	1,395,870	0	4,400,000	(107,614)	192,386
(1,920,000)	(1,431,425)	1,368,575	(54,678)	4,345,322	(113,897)	186,103
(1,940,000)	(1,436,580)	1,363,420	(65,004)	4,334,996	(115,083)	184,917
(2,000,000)	(1,452,044)	1,347,956	(95,981)	4,304,019	(118,642)	181,358
(2,040,000)	(1,462,353)	1,337,647	(116,632)	4,283,368	(121,015)	178,985
(2,100,000)	(1,477,817)	1,322,183	(147,609)	4,252,391	(124,574)	175,426
(2,160,000)	(1,493,280)	1,306,720	(178,586)	4,221,414	(128,134)	171,866
(2,280,000)	(1,524,208)	1,275,792	(240,540)	4,159,460	(135,252)	164,748
(2,300,000)	(1,529,362)	1,270,638	(250,866)	4,149,134	(136,439)	163,561
(2,400,000)	(1,555,135)	1,244,865	(302,494)	4,097,506	(142,371)	157,629
(2,420,000)	(1,560,290)	1,239,710	(312,820)	4,087,180	(143,557)	156,443
(2,450,000)	(1,568,022)	1,231,978	(328,308)	4,071,692	(145,337)	154,663
(2,640,000)	(1,616,990)	1,183,010	(426,402)	3,973,598	(156,608)	143,392
(2,760,000)	(1,647,918)	1,152,082	(488,356)	3,911,644	(163,726)	136,274
(2,880,000)	(1,678,845)	1,121,155	(550,310)	3,849,690	(170,845)	129,155
(3,000,000)	(1,709,773)	1,090,227	(612,264)	3,787,736	(177,963)	122,037
(3,120,000)	(1,740,700)	1,059,300	(674,218)	3,725,782	(185,082)	114,918
(3,240,000)	(1,771,627)	1,028,373	(736,172)	3,663,828	(192,200)	107,800
(3,360,000)	(1,802,555)	997,445	(798,126)	3,601,874	(199,319)	100,681
(3,480,000)	(1,833,482)	966,518	(860,080)	3,539,920	(206,438)	93,562
(3,500,000)	(1,838,637)	961,363	(870,406)	3,529,594	(207,624)	92,376
(3,600,000)	(1,864,410)	935,590	(922,034)	3,477,966	(213,556)	86,444
(3,720,000)	(1,895,337)	904,663	(983,988)	3,416,012	(220,675)	79,325
(3,840,000)	(1,926,265)	873,735	(1,045,942)	3,354,058	(227,793)	72,207
(3,960,000)	(1,957,192)	842,808	(1,107,896)	3,292,104	(234,912)	65,088
(4,000,000)	(1,967,501)	832,499	(1,128,547)	3,271,453	(237,285)	62,715
(4,080,000)	(1,988,120)	811,880	(1,169,850)	3,230,150	(242,030)	57,970
(4,200,000)	(2,019,047)	780,953	(1,231,804)	3,168,196	(249,149)	50,851
(4,320,000)	(2,049,975)	750,025	(1,293,758)	3,106,242	(256,267)	43,733
(4,440,000)	(2,080,902)	719,098	(1,355,712)	3,044,288	(263,386)	36,614

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(4,560,000)	(2,111,830)	688,170	(1,417,666)	2,982,334	(270,504)	29,496
(4,610,000)	(2,124,716)	675,284	(1,443,480)	2,956,520	(273,470)	26,530
(4,680,000)	(2,142,757)	657,243	(1,479,620)	2,920,380	(277,623)	22,377
(4,755,000)	(2,162,087)	637,913	(1,518,341)	2,881,659	(282,072)	17,928
(4,800,000)	(2,173,684)	626,316	(1,541,574)	2,858,426	(284,741)	15,259
(4,840,000)	(2,183,994)	616,006	(1,562,225)	2,837,775	(287,114)	12,886
(4,900,000)	(2,199,457)	600,543	(1,593,202)	2,806,798	(290,674)	9,326
(4,910,598)	(2,202,189)	597,811	(1,598,674)	2,801,326	(291,302)	8,698
(5,000,000)	(2,256,342)	543,658	(1,618,723)	2,781,277	(291,602)	8,398
(6,000,000)	(2,383,742)	416,258	(2,324,655)	2,075,345	(291,602)	8,398
(7,000,000)	(2,383,742)	416,258	(3,157,989)	1,242,011	(291,602)	8,398
(7,500,000)	(2,383,742)	416,258	(3,574,655)	825,345	(291,602)	8,398
(9,000,000)	(2,800,000)	0	(4,400,000)	0	(300,000)	0

C.4.3 Distribution Within States for the Priority Shortage Allocation Model

C.4.3.1 Introduction

In accordance with Article II(B)(3) of the Consolidated Decree and Section 301(b) of the CRBPA, the Secretary has the authority to declare and allocate shortages to the Lower Division States. Some explicit guidance is given by the Supreme Court and Congress with regard to how shortages would be allocated according to priority, and additional detail is based on intra-state priority systems including as established by law and contract, and federal water delivery contracts executed pursuant to Section 5 of the Boulder Canyon Project Act.

To estimate the impacts of given levels of shortage, assumptions were made with regard to how shortages might be shared. These assumptions are made to facilitate analysis of potential impacts and are not intended to represent current or future policy with respect to shortage allocation. The Shortage Allocation Model is not designed to replicate some of the annual processes that must be undertaken in determining the quantity of water that can be approved for diversion by specific users.

C.4.3.2 General State Assumptions

Entitlement holders with multiple priorities are assumed to divert their highest-priority water first, until it is fully utilized, regardless of whether specific geographic restrictions may exist for the actual use of various priorities.

With the exception of PPRs, entitlement holders within a priority or sub-priority share in a pro rata distribution of available water on the basis of entitlement, unless another distribution is prescribed by contract or other determination. Within priorities other than PPRs, priority dates are not considered except as they pertain to grouping entitlements by priority.

PPRs (on a consumptive use or equivalent basis) are not included in the distribution of shortage within each state; they are subtracted from the water calculated to be available to each state, which water is then distributed in satisfaction of non-PPR entitlements, and the PPRs are accounted for in a separate PPR worksheet. A fill order is assumed for PPRs (see **Section C.4.1**).

C.4.3.3 Nevada Assumptions

Nevada has eight water delivery priorities as established in the Robert B. Griffith Water Project Contract No. 7-07-30-W0004, as amended, for delivery of Colorado River water between the U.S. and the State of Nevada; the contract also provides for the Southern Nevada Water Authority (SNWA) to divert the balance of any remaining un-allocated, unused, and surplus water in Nevada. **Table C-7** on the following page summarizes that priority system, which is also available at https://www.usbr.gov/lc/region/g4000/contracts/entitlements.html.

Deliveries to Nevada are no longer assumed to be constrained by Lake Mead surface elevation as assumed in the 2007 FEIS; however, the Shortage Allocation Model does not reflect the effect of potential system shortages or physical limitations on access to water.

The Shortage Allocation Model does not reflect any arrangements by the SNWA member agencies that may exist regarding the distribution of water amongst themselves during a Shortage Condition.

C.4.3.4 California Assumptions

Entitlements shown on the following page in **Table C-8** for California priorities one through three exclude the full volume of PPR entitlements held by those same parties, which are subject to a separate priority system (see **Section C.4.1**). Reclamation recognizes that the QSA and related agreements help California parties meet the water needs of PPRs by agreeing that certain parties to the Seven Party Agreement would make water available to satisfy the requirements of the PPR holders while keeping the priorities within the Seven Party Agreement[10] intact.

In addition, the Colorado River Water Delivery Agreement (CRWDA) quantifies, for a specific term of years, the deliveries under certain Colorado River water entitlements within shared priorities so that transfers may occur, facilitating California limiting its use to 4.4 mafy. In particular, for the term of the CRWDA, quantification of Priority 3(a) was effected through caps on water deliveries to Imperial Irrigation District (consumptive use of 3.1 million acre-feet per year) and CVWD (consumptive use of 330,000 acre-feet per year). Priorities 1, 2, 3(b), 6(b), 7, and PPRs are not affected, and the CRWDA provides that underlying water delivery contracts with the Secretary remain in full force and effect.

[10] The Seven Party Agreement provides that "The total beneficial consumptive use under priorities stated in Sections 1, 2 and 3 of this article shall not exceed 3,850,000 acre-feet of water per annum."

Table C-7
Framework for Priority-Based Distribution of Available Water Within Nevada

Priority	Entitlement Holder	Contract No.	Priority Date	Use	Entitlements		
					Diversion (afy)	CU or Estimated Equivalent (afy)[1]	Cumulative CU (afy)
9th	Any contracts dated after 3-2-1992, SNWA Contract	-	-	-	-	-	-
8th – Balance & Surplus	Southern Nevada Water Authority	2-07-30-W0266	3/2/1992	Domestic	balance + surplus	92,717	
	TOTAL	-	-	-	-	92,717	291,302
8th	Big Bend Water District	2-07-30-W0269	3/2/1992	Domestic	10,000	4,900	
	Robert B. Griffith Project Sub. to City of Boulder City (8,918 af) Sub. to City Henderson (27,021 af) Sub. to City of North Las Vegas (26,635 af) Sub. to Las Vegas Valley Water District (232,426 af)	7-07-30-W0004	3/2/1992	Domestic	304,000	158,080	
	TOTAL	-	-	-	**314,000**	162,980	198,586
7th	Southern Nevada Water Authority (Formerly Boy Scouts of America)	9-07-30-W0011	11/8/1978	Domestic	10	5	
	Bureau of Reclamation (includes Sportsman Park)	Secretarial Res.	11/9/1998	Domestic	300	147	
	Nevada Dept. of Wildlife (formerly Nevada Dept. of Fish & Game)	14-06-300-2405	10/18/1972	Domestic		25	
	US Air Force (4.0 kaf) (Delivery from SNWA)	F26600-78-DOO11, amended by F-26600-01-D-A111 (Included in 07-07-30-W0004 in P8)	1/23/1978, amended 5/1/2000	-	4,000	2,080	
	TOTAL	-	-	-	**4,310**	2,257	35,606
6th	Las Vegas Valley Water District	14-06-300-2130	9/22/1969	Domestic	15,407	8,012	
	TOTAL	-	-	-	**15,407**	8,012	33,348
5th	Lakeview Company (Hacienda Casino)	14-06-300-1523	2/12/1965	Domestic	0	0	
	Pacific Coast Building Products, Inc. (PABCO)	5-07-30-W0089	6/19/1985	Domestic	928	483	
	TOTAL	-	-	-	**928**	483	25,337

Priority	Entitlement Holder	Contract No.	Priority Date	Use	Entitlements		
					Diversion (afy)	CU or Estimated Equivalent (afy)[1]	Cumulative CU (afy)
4th	Henderson Water Company (formerly BMI/Basic Water Company)	14-06-300-2083	9/18/1969	Domestic	8,208	4,268	
	City of Henderson	0-07-30-W0246	9/18/1969	Domestic	15,878	8,257	
	Southern Nevada Water Authority (From Basic Water Company)	2-07-30-W0266	9/18/1969	Domestic	14,950	7,774	
	TOTAL	-	-	-	**39,036**	20,299	24,854
3rd	Boulder City[2]	14-06-300-978	5/15/1931	Domestic	5,876	3,056	
	TOTAL	-	-	-	5,876	3,056	4,556
2nd	Lake Mead National Recreation Area, Executive Order No. 5339	1964 Decree	4/25/1930	Domestic	Unquantified, estimated ~1,500	1,500	
	TOTAL	-	-	-	**1,500**	1,500	1,500
NEVADA TOTALS	-	-	-	-	381,057	291,302	-

Note: CU means Consumptive Use. All units are in acre-feet per year. The Cumulative CU column is included as a reference for the estimated amount of water that would need to be available to Nevada priorities two through eight to fulfill a given priority on this table.
Subcontracts are displayed below the Entitlement Holder and indented five spaces.
In a shortage, PPRs are delivered water in order of priority date regardless of state lines. PPRs are not included in this table, and they are accounted for in a separate PPR worksheet.
[1]Historical Decree Accounting data were used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS. For purposes of modeling, these values are assumed to be generally representative of return flow conditions for the specified users, and match CRSS inputs; these values were used to estimate the consumptive use equivalent of diversion entitlements.
[2]Boulder City's entitlement is delivered through the Robert B. Griffith Project; historically there have been no return flows from Boulder City, but proposals are under review to begin generating return flows. It will be considered reasonably foreseeable for this to occur over the period of analysis, therefore Boulder City's CU/Div ratio is assumed to be the same as for the Southern Nevada Water Authority as a whole.

Table C-8
Framework for Priority-Based Distribution of Available Water Within California

Priority[1]	Entitlement Holder	Contract No.	Priority Date	Use	Diversion Entitlement (afy)	CU Entitlement (afy)	Estimated Use	
							CU or Estimated Equivalent (afy)[2]	Cumulative CU (afy)
4th	The Metropolitan Water District of Southern California (MWD) (4)	I1r-645	1930, 1931	Domestic	-	550,000	388,002	-
	TOTAL	-	-	-	**0**	**550,000**	**388,002**	**1,598,674**
3rd	Palo Verde Irrigation District (3b) – Lower Palo Verde Mesa Lands[3]	PVID20733C_P5	1933	Irrigation	≤16,000 acres	Unquantified	5,000	
	Coachella Valley Water District (CVWD) (3a)[4]	I1r-781	1934	Irrigation	-	330,000	330,000	
	Imperial Irrigation District (IID) (3a)[5]	I1r-747	1932	Irrigation	-	500,000	500,000	
	TOTAL[3]	-	-	-	-	-	**835,000**	**1,210,672**
2nd	Yuma Project, Reservation Division (Bard Unit Only – Indian Unit Under PPRs)[6]	Water Certificates	1905	Irrigation	≤25,000 acres	-	7,294	
	TOTAL	-	-	-	-	-	**7,294**	**375,672**
1st	Palo Verde Irrigation District – Valley Lands (1)	PVID20733C_P2	1933	Irrigation	≤104,500 acres	Unquantified	368,378	
	TOTAL	-	-	-	-	-	**368,378**	**368,378**
-	**CALIFORNIA TOTALS**	-	-	-	-	-	**1,598,674**	-

Notes: CU means Consumptive Use; all units are in afy (acre feet per year). The Cumulative CU column is included as a reference for the estimated amount of water that would need to be available to California priorities one through four to fulfill a given priority on this table.

[1]Priorities are based on the California Seven Party Agreement, modified for the PPRs identified by the Consolidated Decree (which are accounted for in the PPRs table).

[2]Historical Decree Accounting data were used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS, including estimating the consumptive use equivalent of diversion entitlements. Unless otherwise noted, modeled entitlements match CRSS.

[3]PVID's P3(b) entitlement for the Lower Palo Verde Mesa Lands is unquantified. For modeling purposes, an estimated CU equivalent of 5.0 kaf was assumed based on conversations with PVID.

[4]QSA transfers and exchanges are not modeled in the Shortage Allocation Model, a difference from CRSS. For modeling purposes, CVWD P3(a) was shorted before IID P3(a) based on the 1934 Agreement of Compromise; no interpretation of the agreement is intended by this modeling assumption.

[5]Non-Colorado River water is pumped from the Lower Colorado Water Supply Project wellfield and discharged into the All-American Canal for delivery to IID. IID forbears the consumptive use of an equivalent amount of Colorado River, up to a maximum of 10.0 kaf per year, to make such water available, via exchange, to the Lower Colorado Water Supply Project beneficiaries (includes MWD and the City of Needles and its subcontractors). For purposes of the shortage allocation model, the 10.0 kaf is included in IID's estimated CU equivalent; if the exchange could not be completed in a given year, it is assumed that IID would divert this amount from the Colorado River.

[6]The Yuma Project CU Estimated Equivalent is based on historical consumptive use of the Bard Unit, minus the CU from PPR 28, which is accounted for in the PPRs table. The Yuma Project Reservation Division Indian Unit is not accounted for here since it is covered by PPR 23, also listed in the PPRs table. This estimated CU equivalent differs from CRSS by 5.0 kaf due to CRSS modeling a seasonal fallowing program.

The CRWDA does not limit the Secretary's authority under Article II(B)(3) of the Consolidated Decree in *Arizona v. California* to allocate water in times of shortage. If, however, less than 3,850,000 acre-feet of Colorado River water is made available to entities in California under Priorities 1 through 3 during the year, the Secretary agrees in the CRWDA to deliver any water made available to Imperial Irrigation District and CVWD in the manner provided for in any shortage sharing provisions agreed upon by Imperial Irrigation District, CVWD, MWD, and San Diego County Water Authority prior to or concurrent with the execution of the CRWDA. During development of this EIS in 2024, unresolved issues pertaining to interpretation of the priority language contained within California water delivery agreements resulted in Reclamation retaining the level of detail from Appendix G of the 2007 FEIS, pending additional feedback from the parties. Reclamation also recognizes pre-existing issues raised in connection with the Imperial Irrigation District water delivery agreement with the Secretary, which provided for use of Imperial Irrigation District's entitlement "within the boundaries of the District."

In consequence, Reclamation made the following modeling assumptions, which are intended to facilitate only the comparative analysis of alternatives for this EIS.

- The quantified entitlements in Exhibit B of the CRWDA for Imperial Irrigation District and CVWD were modeled in the Priority Shortage Allocation Model, as this is a pre-requisite to quantifying estimated shortage to any of the parties within California priorities one through three. Without this step, further monetization of estimated socioeconomic impacts on agriculture could not occur, but the model does not limit priorities one through three to the volume stated in the Seven Party Agreement due to the above-described issues regarding transfers.
- Within priority 3a, CVWD's, entitlement is modeled as subordinate to Imperial Irrigation District's entitlement in accordance with the February 14, 1934 Agreement of Compromise; however, no opinion is expressed or implied on the part of the U.S. or the non-Federal parties as to how administration of that agreement during a Shortage Condition may affect the parties' rights pursuant to various arrangements.
- QSA transfers and exchanges were not modeled in the Priority Shortage Allocation Model, as the relevant agreements do not provide sufficient detail to model a system of priority among the transfers. This is also consistent with assumptions for the Priority Shortage Allocation Model as a whole, which models shortage at the (permanent) entitlement level.

Although MWD has a fourth priority Seven Party Agreement entitlement of 550 kaf, MWD's consumptive use equivalent entitlement is calculated (for modeling purposes) to equal the balance of California's apportionment after full use of higher priority entitlements. During a shortage, MWD may acquire water supplies from other sources, and those arrangements are not modeled in the Priority Shortage Allocation Model.

Entitlements associated with each California entitlement holder are available at: https://www.usbr.gov/lc/region/g4000/contracts/entitlements.html.

The San Luis Rey Indian Water Rights Settlement Act, 102 Stat. 4000 (1988), as amended and supplemented by Section 211 of the Act of October 27, 2000, 114 Stat. 1441A-70, directed the

Secretary to permanently furnish annually up to 16,000 acre-feet per year of Colorado River water from the lining of the All-American and Coachella Canals to be made available for purposes of the San Luis Rey Indian water rights settlement. That water is not modeled in the Priority Shortage Allocation Model as being subject to shortage in accordance with the California priority system.

C.4.3.5 Arizona Assumptions

Entitlements associated with each Arizona entitlement holder are available at: https://www.usbr.gov/lc/region/g4000/contracts/entitlements.html.

Water available to entitlement holders in Arizona is distributed through each priority according to the following assumptions. These assumptions do not necessarily reflect operational procedure, but they are necessary to produce a general approximation of the effect of shortages on specific priorities and entitlements for this EIS.

C.4.3.5.1 Arizona Priority Two and Three Assumptions

Arizona priority two is for Secretarial Reservations and Perfected Rights established or effective prior to September 30, 1968. Arizona priority three is for entitlements pursuant to contracts between the U.S. and water users in the State of Arizona executed on or before September 30, 1968. The second and third priorities are coequal.

The available supply to Arizona priorities two and three is calculated as the available supply to Arizona minus the sum (597,811 af) of Arizona's first priority (PPR) entitlements on a consumptive use (or estimated equivalent) basis. That supply is divided between priorities two and three in proportion to the sum of the consumptive use (or equivalent) entitlements within each priority: about 10 percent to priority two and about 90 percent to priority three. The following assumptions for distribution within those priorities consider contract-specific priority language.

Water available to priority two is distributed among its five entitlements in proportion to their consumptive use (or equivalent) entitlement relative to the total for priority two.

Water available to priority three is distributed among its 28 entitlements[11] in six groups according to project and/or division or pertinent contract terms. The alphanumeric sub-priority naming conventions for the six groups (shown in **Table C-9** on the following page) are not operational or contractual designations, and they are only used as an organizational tool specific to this analysis. Five of the six groups are assumed to be coequal within priority three, and they are distributed water in proportion to the sum of the consumptive use (or equivalent) entitlements within each group, relative to the total for all five groups. They are discussed in detail in the sections that follow.

[11] As of February 7, 2025.

Table C-9
Framework for Priority-Based Distribution of Available Water Within Arizona Priorities 2 and 3

Priority	Water Allocation % by Priority	Sub-Priority*	Project	Division	Water Allocation % by Project/Division	Entitlement Holder	Contract No.	Priority Date	Use	Entitlements: Diversion (AFY)	Entitlements: CU or *Estimated Equivalent* (AFY)
2	9.72%	N/A	N/A	N/A	N/A	Cibola National Wildlife Refuge[5]	Secretarial Res.	8/21/1964	Domestic	27,000	16,793
						Lake Mead National Recreation Area	Consolidated Decree	4/25/1930	Domestic	unquantified	*343*
						Bureau of Reclamation - Davis Dam	Secretarial Res.	4/26/1941	Domestic	100	*7*
						Imperial National Wildlife Refuge	Consolidated Decree	2/14/1941	Domestic	28,000	23,000
						Havasu Lake National Wildlife Refuge	Consolidated Decree	1/22/1941	Domestic	41,839	37,399
										P2 Total	**77,542**
3	90.28%	3b	Boulder Canyon		Remainder	City of Yuma	14-06-W-106	11/12/1959	Domestic		48,522
											Project/Division Subtotal **48,522**
		3a5 Subordinate	Gila	Yuma Mesa	32.66%	Union Pacific Railroad (formerly Southern Pacific Co.)	14-06-303-1524	12/21/1959	Domestic	48	*25*
						Kaman, Inc.	14-06-303-1555	12/2/1959	Domestic	2	*2*
						Department of the Navy, MCAS	14-06-300-937	1/1/1959	Domestic	3,000	*3,000*
						City of Yuma (cemetery)	14-06-303-1078	5/1/1956	Domestic	60	*60*
						Yuma Mesa Fruit Growers' Association	14-06-303-1196	10/1/1956	Domestic	15	*15*
						Desert Lawn Memorial Park Association	14-06-300-1079	5/1/1956	Domestic	200	*138*
						Sturges, Harold	I76R-733	1/1/1952	Irrig.	335	*335*
						Sturges, Irma	I76R-735	1/1/1952	Irrig.	385	*385*
		3a5				**Yuma Mesa Irrigation & Drainage District (10,000af M&I)**	5-07-30-W0095	5/26/1956	Both		141,519
						Yuma Irrigation District (5,000af M&I)	5-07-30-W0093	7/23/1962	Both		67,278
						North Gila Valley Irrigation and Drainage District (2,500af M&I)	5-07-30-W0094	5/12/1953	Both		*6,731*
											Project/Division Subtotal ***219,488***
		3a4	Gila	Wellton-Mohawk	41.37%	**Wellton-Mohawk Irrigation and Drainage District (12,000af M&I)**	1-07-30-W0021	3/4/1952	Both		278,000
											Project/Division Subtotal ***278,000***
		3a3	Various		11.42%	Ak-Chin Indian Community[3]	1985 Settlement Contract	1/1/1956	Both	50,000	*50,000*
						Chandler (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0235	3/4/1952	Domestic	4,278	*4,278*
						Gilbert (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0241	3/4/1952	Domestic	6,762	*6,762*
						Glendale (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0236	3/4/1952	Domestic	3,000	*3,000*
						Mesa (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0239	3/4/1952	Domestic	2,760	*2,760*
						Phoenix (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0240	3/4/1952	Domestic	5,000	*5,000*
						Scottsdale (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0237	3/4/1952	Domestic	100	*100*
						Tempe (Salt River Pima-Maricopa Exchange)[3]	9-07-30-W0238	3/4/1952	Domestic	100	*100*
						Department of the Army - Yuma Proving Ground	I76r-696	6/12/1951	Domestic	1,129	*1,129*
						Gila Monster Farms (formerly Sturges)	6-07-30-W0337	1/1/1952	Irrig.	6,285	*3,582*
											Project/Division Subtotal ***76,711***
		3a2 Subordinate	Yuma	Valley	11.82%	Yuma Union High School District	14-06-303-179	1/1/1953	Domestic	200	*148*
		3a2				**Yuma County Water Users' Association (14,701af M&I includes YA**	14-06-300-621 & Certificates	4/1/1957	Both	unquantified	*79,304*
											Project/Division Subtotal ***79,452***
		3a1 Subordinate	Yuma Auxiliary		2.73%	University of Arizona	14-06-300-144	1/1/1954	Irrig.	1,088	*1,088*
						Desert Lawn Memorial Park Association, Inc.[4]	14-06-300-2587	5/30/1975	Domestic	360	*248*
						Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	14-06-303-528	12/23/1953	Irrig.	120	*120*
		3a1				**Unit B Irrigation & Drainage District**	14-06-300-44	12/22/1952	Irrig.	unquantified	*16,886*
											Project/Division Subtotal ***18,343***
Grand Total	**100.00%**										
											P3a Total **671,995**
											P3 Total **720,517**
											P 2 & 3 Grand Total **798,059**

The Yuma Mesa Division of the Gila Project

Approximately 33 percent of the available priority three water, up to the limit of the sum of the consumptive use (or equivalent) entitlements within the Division, is distributed among the Division's 11 entitlements. That water is first made available to Yuma Mesa Irrigation and Drainage District, Yuma Irrigation District, and North Gila Valley Irrigation and Drainage District coequally in proportion to their consumptive use entitlements.[12]

Any water remaining for the Division after satisfaction of the district contracts is made available to Union Pacific Railroad, Kaman, Department of the Navy (Marine Corps Air Station), City of Yuma (Cemetery), Yuma Mesa Fruit Growers Association, Desert Lawn Memorial Park Association, Harold Sturges, and Irma Sturges, coequally in proportion to their consumptive use equivalent entitlements.[13]

The Wellton-Mohawk Division of the Gila Project

Approximately 43 percent of the available priority three water, up to the limit of Wellton-Mohawk Irrigation and Drainage District's consumptive use entitlement, is made available to the District.[11]

The Yuma Project

Approximately 11 percent of the available priority three water is first made available to the Yuma County Water Users Association up to the limit of its consumptive use equivalent entitlement. Any water remaining for the Yuma Project after satisfaction of the Association contract is made available to Yuma Union High School District.[12]

The Yuma Auxiliary Project

Approximately 2.0 percent of the available priority three water, up to the limit of the sum of the consumptive use equivalent entitlements within the Yuma Auxiliary Project, is distributed among the Yuma Auxiliary Project's three entitlements. That water is first made available to Unit B Irrigation and Drainage District up to the limit of its consumptive use equivalent entitlement. Any water remaining for the Yuma Auxiliary Project after satisfaction of the District contract is made available to the University of Arizona, the successor to Camille Allec, Jr., and Desert Lawn Memorial Park Association (for Contract No. 14-06-300-2587).[12]

Various Entitlements

A group of 10 entitlements established under various authorities shares approximately 12 percent of the available priority three water, up to the limit of the sum of the consumptive use (or equivalent) entitlements within the group. Water is distributed to the Ak-Chin Indian Community; the Arizona cities of Chandler, Gilbert, Glendale, Mesa, Phoenix, Scottsdale, and Tempe; the Department of the Army (Yuma Proving Ground); and Gila Monster Farms coequally in proportion to their consumptive use (or equivalent) entitlements. The distribution of water is stated in terms of

[12] Domestic use within each district's entitlement is assumed to be subordinated to irrigation use in the district but is not itemized separately.

[13] Water use is subject to availability and is assumed not to be detrimental to water service for the project or prior appropriators.

quantities available at the mainstream point of diversion, and no assumptions are made about the further distribution of priority three water delivered through the CAP.

The City of Yuma

The City of Yuma receives all remaining priority three water, up to the limit of its consumptive use entitlement (minus a portion assumed to be satisfied by PPR No. 21), reflecting that water delivery under its Contract No. 14-06-W-106 is subject to the prior fulfillment of contracts for the diversion of Colorado River water at Imperial Dam and for the delivery of such water through the Gila Gravity Main Canal or the All-American Canal for the irrigation of lands in the State of Arizona.

C.4.3.5.2 Arizona Priority Four Assumptions

For calendar years 2022 through 2026, Reclamation implemented[14] the State of Arizona's August 6, 2009, Arizona Shortage Sharing Recommendation and the "pool" approach described by letter dated January 25, 2021, to inform approval of fourth priority water orders, consistent with Section 301(b) of the CRBPA and the contracts providing that the fourth priority Colorado River water entitlements of the P4(i) or 'mainstream' users and the CAP (P4(ii)) are coequal.

The Priority Shortage Allocation Model uses a simplified version of the fourth priority shortage sharing procedure that is consistent with other assumptions for shortage modeling under long-term steady state conditions. It subtracts the sum of Arizona priority 1 through 3 entitlements (on a consumptive use basis) and the Arizona shortage volume from Arizona's Colorado River water apportionment to derive the fourth priority supply on a consumptive use basis. The P4(i) available supply is calculated as 10 percent[15] of the fourth priority supply on a consumptive use basis, not to exceed the total of the consumptive use equivalents of entitlements in the P4(i) pool (108,958 afy as modeled). The remainder of the fourth priority supply is available for diversion as fourth priority water by the CAP to fulfill CAP contracts and subcontracts.

C.4.3.5.3 P4(i) (Mainstream) Framework and Assumptions

The P4(i) pool is quantified in terms of 164,652 afy of diversions from the Colorado River, which for modeling purposes is converted to a consumptive use total of 108,958 afy with historical Decree Accounting data used to estimate CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS. Shortage to the P4(i) is calculated as the difference between the P4(i) available supply and the total of the consumptive use equivalents of entitlements in the P4(i) pool (108,958 afy as modeled). Shortage to each entitlement within the P4(i) pool is

[14] For example: Reclamation's September 14, 2022, letter notifying interested parties of a Tier 2 Shortage Condition and required DCP contributions in calendar year 2023, and Reclamation's September 28, 2022, letter to the Central Arizona Water Conservation District announcing the calendar year 2023 Available CAP Supply.

[15] Based on the relative volumes of the P4(i) and P4(ii) contracting pools.

borne in proportion to its entitlement[16] relative to the entire pool as quantified by contracts. For purposes of the Priority Shortage Allocation Model, the P4(i) pool includes two outstanding Arizona Department of Water Resources recommendations that have not yet been placed under contract, the 3.5 kafy quantified and reserved for use in a future Navajo-Hopi Indian water rights settlement in accordance with subsection 11.3 of the 2006 Arizona Water Settlement Agreement, and the quantified remainder of the pool which is available for contracting by the Secretary to satisfy current or future tribal and other water needs. (See **Table C-10** below)

Contracts and subcontracts are itemized separately, meaning an entity's total modeled supply may be the sum of multiple distributions.

Table C-10
Framework for Priority-Based Distribution of Available Water Within Arizona P4(i) (Mainstream)

P4(i) Entitlement Holders	Contract Number(s)	Contract Date	Type of Use	Diversion Entitlement in afy	Divided By	Sum of Entitlements in afy (Div. or Equiv.)	Equals	Proportionate Share of P4(i) Pool
Arizona Game and Fish Commission	07-XX-30-W0509	2007	Irrigation	2,838.00	/	164,652	=	1.724%
Arizona State Land Department	4-07-30-W0317	1999	Irrigation	6,607.00	/	164,652	=	4.013%
Beattie Farms, Southwest	05-XX-30-W0446	2006	Irrigation	1,110.00	/	164,652	=	0.674%
Bishop, Alfred F. and Erma Jean Family Trust	21-XX-30-W0718	2022	Irrigation	420.00	/	164,652	=	0.255%
Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	21-XX-30-W0719	2022	Irrigation	126.00	/	164,652	=	0.077%
Perricone Arizona Properties, LLC and Meyer Farms, LLC	09-XX-30-W0539	2024	Irrigation	2,100.00	/	164,652	=	1.275%
Cibola Sportsman's Club, Inc.	21-XX-30-W0717	2022	Irrigation	216.00	/	164,652	=	0.131%
Cibola Valley Irrigation and Drainage District	2-07-30-W0028	1983	Both	7,442.52	/	164,652	=	4.520%
Cocopah Indian Reservation	Consolidated Decree in AZ v. CA	1974	Both	2,026.00	/	164,652	=	1.230%
Curtis, Armon	3-07-30-W0037	1983	Irrigation	300.00	/	164,652	=	0.182%
Gila Monster Farms, Inc.	6-07-30-W0337	1997	Irrigation	1,435.00	/	164,652	=	0.872%
Matador Farms, LLC	17-XX-30-W0628	2024	Irrigation	4,500.00	/	164,652	=	2.733%
Hopi Tribe	04-XX-30-W0432	2004	Irrigation	4,278.00	/	164,652	=	2.598%
JRJ Partners, L.L.C.	06-XX-30-W0448	2007	Irrigation	1,080.00	/	164,652	=	0.656%
Mohave Valley Irrigation and Drainage District	14-06-W-204	1968	Both	35,060.00	/	164,652	=	21.293%
North Baja Pipeline, LLC	04-XX-30-W0433	2005	Both	480.00	/	164,652	=	0.292%
Ogram Boys Enterprises, Inc.	01-XX-30-W0402	2005	Irrigation	924.00	/	164,652	=	0.561%
Ott, Larry and Gina, and Lee C. and Candace M.	18-XX-30-W0639	2018	Irrigation	480.00	/	164,652	=	0.292%
Pasquinelli, Gary J. and Barbara J.	5-07-30-W0065	1986	Irrigation	486.00	/	164,652	=	0.295%
Phillips, Milton and Jean	Recommendation		Irrigation	60.00	/	164,652	=	0.036%
Red River Land Company, LLC	17-XX-30-W0630	2018	Irrigation	300.00	/	164,652	=	0.182%
Western Water, LLC	16-XX-30-W0619	2018	Irrigation	536.48	/	164,652	=	0.326%
Arizona State Land Department	7-07-30-W0358	2004	Domestic	1,534.00	/	164,652	=	0.932%
Arizona State Parks Board - Windsor Beach	7-07-30-W0364	1998	Domestic	90.00	/	164,652	=	0.055%
B&F Investment, LLC	06-XX-30-W0453	2006	Domestic	60.00	/	164,652	=	0.036%
Bullhead City	2-07-30-W0273	1994	Domestic	15,210.00	/	164,652	=	9.238%
Bullhead City (MCWA Subcontract)	Subcontract to 04-XX-30-W0431	2004	Domestic	2,139.00	/	164,652	=	1.299%
Bullhead City (MCWA Subcontract)	Subcontract No. 95-102 to 5-07-30-W0320	1995	Domestic	7,000.00	/	164,652	=	4.251%

[16] Historically Arizona P4(i) entitlements have been quantified on a diversion basis. More recently, the Bureau of Land Management's and Town of Queen Creek's Arizona P4(i) entitlements have specified consumptive use volumes (consumptive use = diversions minus return flows). These entitlements are shown in **Table C-5** as their diversion equivalents (consumptive use + historical or current return flows = diversion equivalent) for modeling purposes because distribution during shortage within the Arizona P4(i) pool is assumed to be administered in proportion to all users' diversion volumes, not in proportion to consumptive use volumes, for uniformity and consistency. The diversion equivalency volumes listed in **Table C-9** are necessary to analyze the distribution of the Arizona P4(i) entitlements with a uniform metric, do not modify the entitlements, and are consistent with applicable contracts and agency decision documents.

P4(i) Entitlement Holders	Contract Number(s)	Contract Date	Type of Use	Diversion Entitlement in afy	Divided By	Sum of Entitlements in afy (Div. or Equiv.)	Equals	Proportionate Share of P4(i) Pool
Bureau of Land Management (diversion equivalent)	8-07-30-W0373	2000	Domestic	6,169.00	/	164,652	=	3.747%
Crystal Beach Water Conservation District	6-07-30-W0352	1997	Domestic	132.00	/	164,652	=	0.080%
Ehrenburg Improvement District	8-07-30-W0006	2020	Domestic	735.00	/	164,652	=	0.446%
EPCOR Water Arizona Inc.	20-XX-30-W0690	2021	Domestic	1,874.00	/	164,652	=	1.138%
Fisher's Landing Water and Sewer Works, L.L.C.	06-XX-30-W0450	2006	Domestic	53.00	/	164,652	=	0.032%
Frontier Communications West Coast Inc.	14-06-300-2506	1974	Domestic	1.00	/	164,652	=	0.001%
Gold Dome Mining Corporation	0-07-30-W0250	1990	Domestic	7.00	/	164,652	=	0.004%
Golden Shores Water Conservation District	9-07-30-W0203	1989	Domestic	2,000.00	/	164,652	=	1.215%
GSC Farm, LLC	13-XX-30-W0571	2013	Domestic	69.93	/	164,652	=	0.042%
Hillcrest Water Company	5-07-30-W0078	1985	Domestic	84.00	/	164,652	=	0.051%
Lake Havasu City	3-07-30-W0039	1995	Domestic	19,192.70	/	164,652	=	11.657%
Lake Havasu City (MCWA Subcontract)	Subcontract to 04-XX-30-W0431	2004	Domestic	2,139.00	/	164,652	=	1.299%
Lake Havasu City (MCWA Subcontract)	Subcontract No. 95-101 to 5-07-30-W0320	1995	Domestic	7,250.00	/	164,652	=	4.403%
La Paz County	08-XX-30-W0530	2008	Domestic	350.00	/	164,652	=	0.213%
Martinez Lake Cabin Sites	Recommendation		Domestic	23.00	/	164,652	=	0.014%
McAlister Family Trust	7-07-30-W0355	1998	Domestic	40.00	/	164,652	=	0.024%
Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Subcontract No. 09-101 to 5-07-30-W0320	1995	Domestic	1,250.00	/	164,652	=	0.759%
Mohave Water Conservation District	9-07-30-W0012	1979	Domestic	1,800.00	/	164,652	=	1.093%
Mohave Water Conservation District (MCWA Subcontract)	Subcontract No. 95-103 to 5-07-30-W0320	1995	Domestic	3,000.00	/	164,652	=	1.822%
Parker, Town of	2-07-30-W0025	1982	Domestic	1,030.00	/	164,652	=	0.626%
Quartzsite, Town of	7-07-30-W0353	1999	Domestic	1,070.00	/	164,652	=	0.650%
Queen Creek, Town of (mainstream diversion equivalent)	20-XX-30-W0689	2023	Domestic	2,843.37	/	164,652	=	1.727%
Roy, Estates of Anna R. and Edward P.	6-07-30-W0124	1986	Domestic	1.00	/	164,652	=	0.001%
Shepard Water Company, Incorporated	08-XX-30-W0535	2009	Domestic	50.00	/	164,652	=	0.030%
Somerton, City of	03-XX-30-W0419	2006	Domestic	750.00	/	164,652	=	0.456%
Springs Del Sol Domestic Water Improvement District	08-XX-30-W0524	2008	Domestic	100.00	/	164,652	=	0.061%
TV Marble Canyon AZ, LLC	21-XX-30-W0711	2022	Domestic	70.00	/	164,652	=	0.043%
Water Reserved by the Secretary for a Navajo-Hopi Settlement	-	-	-	3,500.00	/	164,652	=	2.126%
Unallocated 4th Priority Mainstream Water	-	-	-	10,230.00	/	164,652	=	6.213%
Total	-	-	-	**164,652**	-	-	-	**100%**

Notes:
The Town of Queen Creek's "mainstream diversion equivalent" is calculated using GSC Farm, LLC's historical CU/Diversion ratio of 0.715; available water on a mainstream diversion equivalent basis would be converted back to CU for conveyance through the Central Arizona Project as provided in the related contracts, but this table does not make the calculation of water available for diversion. Bureau of Land Management's diversion equivalent is calculated with historical Decree Accounting data used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS.
With the exception of Bureau of Land Management and Town of Queen Creek, water is contracted in this pool on a diversion basis, but CU shortage impacts are calculated for the purpose of analysis.
See Arizona Third Priority for Desert Lawn Memorial Park Association, Inc., Contract No. 14-06-300-2587.

For simplicity and transparency in avoiding repeated conversions between diversion and consumptive use, the Priority Shortage Allocation Model calculates each entitlement's shortage by multiplying its proportionate share of the pool on a diversionary basis by the P4(i) shortage in terms of consumptive use.

C.4.3.5.4 CAP Framework and Assumptions

In the Priority Shortage Allocation Model, Arizona priority three Colorado River water entitlements delivered through the CAP are assumed to be satisfied consistent with their Colorado River third priority, and Arizona P4(i) water transported through the CAP is assumed to be satisfied according to its priority.

The CAP Master Repayment Contract (Contract No. 14-06-W-245, Amendment No. 2, dated November 30, 2007) defines the Available CAP Supply as all fourth priority water available for delivery through the CAP, water available from CAP dams and reservoirs other than Modified

Roosevelt Dam, and return flows captured by the Secretary for CAP use. Available CAP Supply is used in contractual determinations related to a CAP Time of Shortage and the distribution of water among CAP contractors and subcontractors. For the purpose of the Priority Shortage Allocation Model, fourth priority water available to CAP for diversion from the mainstream, calculated as described above in **Section C.4.3.5.2**, is converted to Available CAP Supply through the addition of 7,143 afy of water estimated to be available from the CAP dam and reservoir (New Waddell Dam and Lake Pleasant) and the subtraction of 71.4 kafy representing estimated CAP system loss associated with the conveyance of P4(ii) water; CAP return flows are not currently captured.

Terms and conditions for priority in case of shortage to the Available CAP Supply relate only to CAP fourth priority water (P4(ii)) and the other two supplies listed in the previous paragraph. Certain third priority water transported through the CAP (described in **Section C.4.3.5.1** as being diverted on behalf of the Ak-Chin Indian Community and the Arizona cities of Chandler, Gilbert, Glendale, Mesa, Phoenix, Scottsdale, and Tempe),[17] and any other non-Project water diverted by the CAP from the Colorado River, has separate shortage protocols established by statute and contract. The Priority Shortage Allocation Model attempts to reflect the legislative and contractual terms and conditions applicable to a CAP Time of Shortage, which shortage would impact the distribution of water to CAP contractors and subcontractors. The CAP long-term contractors and subcontractors that receive Available CAP Supply are classified in one of three CAP priority pools: Indian Priority, Municipal and Industrial (M&I) Priority, and Non-Indian Agricultural (NIA) Priority. Modeling assumptions for these CAP priorities integrate the shortage-related provisions of a body of contracts and Secretarial determinations dating from the 1980s through the present, as codified by Congress including through Indian water rights settlement legislation. However, levels of shortage to date have not required the implementation of shortage provisions in all CAP contracts and subcontracts, and their modeling should be understood as theoretical.

Available CAP Supply is first made available to Indian Priority and M&I Priority long-term contracts and subcontracts; at or above an Available CAP Supply of 981,902 af, all Indian Priority allocations (343,079 af total) and M&I Priority allocations (638,823 af total) can be satisfied. Any Available CAP Supply in excess of 981,902 af becomes available to NIA Priority long-term contracts and subcontracts. After all long-term CAP contracts and subcontracts are fulfilled[18], the remaining available water could be ordered under one-year excess contracts; however, under the assumptions of the model regarding full use by Arizona Priorities 1 through 3, there is no remaining water available for excess contracts.

An Available CAP Supply less than 981,902 af is a contractually defined Time of Shortage for the CAP, affecting the Indian Priority and M&I Priority pools. Under that condition, the Available CAP Supply is distributed to the Indian Priority pool as set forth by Article 8.11(c) of the CAP Master

[17] See, e.g., Ak-Chin Water Rights Settlement Act of 1978 (Public Law 95-328), as amended; Salt River Pima-Maricopa Indian Community Water Rights Settlement Act of 1988 (Public Law 100-512), as may be amended.

[18] Under Article 3.(b) of the 1985 Contract Between the U.S. and the Ak-Chin Indian Community to Provide Permanent Water and Settle Interim Water Rights, in any year in which sufficient surface water is available, the Secretary shall deliver certain additional water to the Ak-Chin Indian Community. Such water is assumed to be available if there is unused CAP water after CAP orders under long-term contracts and subcontracts are fulfilled; however, that does not occur under the assumptions of the Shortage Allocation Models or Alternative Distribution Models.

Repayment Contract, with the M&I Priority pool receiving the remainder.[19] Then, those volumes must be used to satisfy the contractors and subcontractors in the priority pool. The Indian Priority supply must be used to satisfy all of the Indian Priority contracts, and is assumed to be controlled by and calculated in accordance with the CAP Master Repayment Contract. Likewise for the M&I Priority supply.

A range of Available CAP Supply from zero to 1,255,317 af, in rounded 10 kaf increments except at pivotal quantities, is presented in **Table C-11** below, showing the distribution of Indian Priority supply, M&I Priority supply, and NIA Priority supply for discrete levels of Available CAP Supply contained within the Priority Shortage Allocation Model.

Table C-11
Discrete Levels and Distribution of Available CAP Supply Modeled in the Shortage Allocation Model

Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	M&I Priority Supply (af)	NIA Priority Supply (af)
1,255,317	Full Supply	343,079	638,823	273,415
1,250,000	Full Supply	343,079	638,823	268,098
1,240,000	Full Supply	343,079	638,823	258,098
1,230,000	Full Supply	343,079	638,823	248,098
1,220,000	Full Supply	343,079	638,823	238,098
1,210,000	Full Supply	343,079	638,823	228,098
1,200,000	Full Supply	343,079	638,823	218,098
1,190,000	Full Supply	343,079	638,823	208,098
1,180,000	Full Supply	343,079	638,823	198,098
1,170,000	Full Supply	343,079	638,823	188,098
1,160,000	Full Supply	343,079	638,823	178,098
1,150,000	Full Supply	343,079	638,823	168,098
1,140,000	Full Supply	343,079	638,823	158,098
1,130,000	Full Supply	343,079	638,823	148,098
1,120,000	Full Supply	343,079	638,823	138,098
1,110,000	Full Supply	343,079	638,823	128,098
1,100,000	Full Supply	343,079	638,823	118,098
1,090,000	Full Supply	343,079	638,823	108,098
1,080,000	Full Supply	343,079	638,823	98,098
1,070,000	Full Supply	343,079	638,823	88,098
1,060,000	Full Supply	343,079	638,823	78,098
1,050,000	Full Supply	343,079	638,823	68,098
1,040,000	Full Supply	343,079	638,823	58,098
1,030,000	Full Supply	343,079	638,823	48,098
1,020,000	Full Supply	343,079	638,823	38,098
1,010,000	Full Supply	343,079	638,823	28,098
1,000,000	Full Supply	343,079	638,823	18,098
990,000	Full Supply	343,079	638,823	8,098

[19] See also the Arizona Water Settlements Act of 2004, Public Law 108-451, section 104(d).

Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	M&I Priority Supply (af)	NIA Priority Supply (af)
981,902	Formula	343,079	638,823	-
980,000	Formula	342,595	637,405	-
970,000	Formula	340,051	629,949	-
960,000	Formula	337,508	622,492	-
950,000	Formula	334,964	615,036	-
940,000	Formula	332,420	607,580	-
930,000	Formula	329,876	600,124	-
920,000	Formula	327,332	592,668	-
910,000	Formula	324,789	585,211	-
900,000	Formula	322,245	577,755	-
890,000	Formula	319,701	570,299	-
880,000	Formula	317,157	562,843	-
870,000	Formula	314,613	555,387	-
860,000	Formula	312,070	547,930	-
853,079	36.37518%	310,309	542,770	-
850,000	36.37518%	309,189	540,811	-
840,000	36.37518%	305,552	534,448	-
830,000	36.37518%	301,914	528,086	-
820,000	36.37518%	298,276	521,724	-
819,828	36.37518%	298,214	521,614	-
810,000	36.37518%	294,639	515,361	-
801,574	36.37518%	291,574	510,000	-
800,000	36.37518%	291,001	508,999	-
790,000	36.37518%	287,364	502,636	-
780,000	36.37518%	283,726	496,274	-
770,000	36.37518%	280,089	489,911	-
760,000	36.37518%	276,451	483,549	-
750,000	36.37518%	272,814	477,186	-
740,000	36.37518%	269,176	470,824	-
730,000	36.37518%	265,539	464,461	-
720,000	36.37518%	261,901	458,099	-
710,000	36.37518%	258,264	451,736	-
700,000	36.37518%	254,626	445,374	-
690,000	36.37518%	250,989	439,011	-
680,000	36.37518%	247,351	432,649	-
670,000	36.37518%	243,714	426,286	-
660,000	36.37518%	240,076	419,924	-
650,000	36.37518%	236,439	413,561	-
640,000	36.37518%	232,801	407,199	-
630,000	36.37518%	229,164	400,836	-
620,000	36.37518%	225,526	394,474	-
610,000	36.37518%	221,889	388,111	-
600,000	36.37518%	218,251	381,749	-
590,000	36.37518%	214,614	375,386	-
580,000	36.37518%	210,976	369,024	-
570,000	36.37518%	207,339	362,661	-

Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	M&I Priority Supply (af)	NIA Priority Supply (af)
560,000	36.37518%	203,701	356,299	-
550,000	36.37518%	200,064	349,936	-
540,000	36.37518%	196,426	343,574	-
530,000	36.37518%	192,788	337,212	-
520,000	36.37518%	189,151	330,849	-
510,000	36.37518%	185,513	324,487	-
500,000	36.37518%	181,876	318,124	-
490,000	36.37518%	178,238	311,762	-
480,000	36.37518%	174,601	305,399	-
470,000	36.37518%	170,963	299,037	-
460,000	36.37518%	167,326	292,674	-
450,000	36.37518%	163,688	286,312	-
440,000	36.37518%	160,051	279,949	-
430,000	36.37518%	156,413	273,587	-
420,000	36.37518%	152,776	267,224	-
410,000	36.37518%	149,138	260,862	-
400,000	36.37518%	145,501	254,499	-
390,000	36.37518%	141,863	248,137	-
380,000	36.37518%	138,226	241,774	-
370,000	36.37518%	134,588	235,412	-
360,000	36.37518%	130,951	229,049	-
350,000	36.37518%	127,313	222,687	-
340,000	36.37518%	123,676	216,324	-
330,000	36.37518%	120,038	209,962	-
320,000	36.37518%	116,401	203,599	-
310,000	36.37518%	112,763	197,237	-
300,000	36.37518%	109,126	190,874	-
290,000	36.37518%	105,488	184,512	-
280,000	36.37518%	101,851	178,149	-
270,000	36.37518%	98,213	171,787	-
260,000	36.37518%	94,575	165,425	-
250,000	36.37518%	90,938	159,062	-
240,000	36.37518%	87,300	152,700	-
230,000	36.37518%	83,663	146,337	-
220,000	36.37518%	80,025	139,975	-
210,000	36.37518%	76,388	133,612	-
200,000	36.37518%	72,750	127,250	-
190,000	36.37518%	69,113	120,887	-
180,000	36.37518%	65,475	114,525	-
170,000	36.37518%	61,838	108,162	-
160,000	36.37518%	58,200	101,800	-
150,000	36.37518%	54,563	95,437	-
140,000	36.37518%	50,925	89,075	-
130,000	36.37518%	47,288	82,712	-
120,000	36.37518%	43,650	76,350	-
110,000	36.37518%	40,013	69,987	-

Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	M&I Priority Supply (af)	NIA Priority Supply (af)
100,000	36.37518%	36,375	63,625	-
90,000	36.37518%	32,738	57,262	-
80,000	36.37518%	29,100	50,900	-
70,000	36.37518%	25,463	44,537	-
60,000	36.37518%	21,825	38,175	-
50,000	36.37518%	18,188	31,812	-
40,000	36.37518%	14,550	25,450	-
30,000	36.37518%	10,913	19,087	-
20,000	36.37518%	7,275	12,725	-
10,000	36.37518%	3,638	6,362	-
-	36.37518%	-	-	-

Through term-limited or temporary arrangements, to the extent that such arrangements may be allowed under specific long-term CAP contracts or other legal authority, CAP contractors and subcontractors may make their water available for end use by others. The Shortage Allocation Model does not replicate those arrangements, and it only provides approximate estimates at the contract or subcontract allocation level that interested parties could then consider in planning for administering their respective arrangements during Shortage Conditions. The CAP contractor, subcontractor, and/or parties to those arrangements would have specific decisions to make during Shortage Conditions to administer those arrangements that Reclamation cannot predict with sufficient certainty to analyze in this EIS.

Unallocated water or water not yet placed under contract (including the Secretary's retention of CAP NIA Priority water consistent with the Arizona Water Settlements Act of 2004, section 104(a)) is not reflected in the distribution of available water and is not shown as bearing shortage. These modeling assumptions reflect only that it cannot be speculated when or whether such water or volumes may be allocated or placed under contract but are not intended to preclude allocations or the entry of contracts consistent with applicable law and authority.

CAP Indian Priority Assumptions

The overall deliverable quantity of Indian Priority supply is calculated as authorized in the 2004 Arizona Water Settlements Act (AWSA) (Public Law 108-451) section 104(d), as reflected in the CAP Master Repayment Contract and described in the previous section. The available Indian Priority supply is then distributed as described in applicable law, contracts, and subcontracts and as noted below.

Shortage to the Ak-Chin Indian Community's Indian Priority irrigation allocation is shown at the allocation level, and it does not reflect the conditional entitlement to a portion of that allocation that is held by the San Carlos Apache Tribe. In addition, the shortages attributed to Indian Priority allocations, pursuant to the internal priority system of the Indian Priority pool, do not account for the existence of external arrangements and commitments that would affect the ultimate impacts of shortage. For example, the ultimate impact of shortage may fall in whole or in part on a lessor who has leased a portion of a contractor's Indian Priority water, but the terms and duration of such leasing arrangements are varied, and the arrangement does not change the underlying allocation-

holder. Shortages attributed to Indian Priority allocations form the basis for operational determinations on a case-by-case basis as necessary to administer shortage consistent with applicable contracts and subcontracts.

Further, the Shortage Allocation Model does not analyze any applicable Secretarial obligations to deliver certain contractors or subcontractors other sources of water in any given year, which might have the effect of offsetting or negating the numerical impacts shown to specific Indian Priority pool allocations and could appear to understate the regional effect of a Colorado River shortage unless the other source(s) of water can be definitively identified and the shortage volume attributed to them. Reclamation declines to speculate about the acquisition of alternative sources of water in this Appendix. This EIS presents the worst-case impacts of a regional loss of supply relative to the quantified volumes of Colorado River water the Secretary has allocated and contracted for and actively administers, rather than attempting to analyze and monetize the loss relative to all sources of water supply any given water user may have available.

For the purpose of calculating water available to individual Indian Priority allocations, the Indian Priority supply is distributed under a set of assumptions consistent with the contracts and relevant Secretarial Decisions, including as published in the Federal Register on March 24, 1983 (1983 ROD), as codified by AWSA section 104(d), yielding the approach described in Exhibit 5.3.4.1 to the Tohono O'odham Settlement Agreement[20], *Secretary's Approach for Determining the Amount of Water Available to the Nation During a Time of Shortage Under 1980 Contract*.

In these calculations, CAP Indian Priority contractors are grouped by "Post-AWSA Contracts" and "Pre-AWSA Contracts" (see **Table C-12** on the following pages), each group with its own calculation of the Indian Priority supply for the purpose of calculating water supply available to individual contractors, reflecting that some shortage-related provisions incorporated into Post-AWSA Contracts do not yet apply to all Indian Priority contracts. The AWSA and related actions provided for a framework that enables consistent administration of both groups of contracts, as described below.

Post-AWSA Contracts are modeled to recognize a shared first priority between all homeland and remaining Indian irrigation allocations in accordance with the 1983 ROD.[21] Pre-AWSA Contracts are modeled to recognize the increase in Gila River Indian Community's irrigation reductions from 10 percent to 25 percent as reflected in the 1983 ROD and later contracts/settlements, and the 1993 Fort McDowell Yavapai Nation settlement's authorized increase in the total Indian Priority allocations from 309,828 af to 343,079 af. All Indian Priority entitlements are assumed to have been fully used on Indian lands, as necessary, during the most recent calendar year which was not a Time of Shortage.

Three stages of implementation of CAP Time of Shortage result from these assumptions, with pivot points at 981,902 af, 853,079 af, and 801,574 af of Available CAP Supply. Formulas for the distribution of available Indian Priority supply to individual allocations over each of these stages are

[20] **Attachment C-1** to this **Appendix C**

[21] The terms "homeland" and "irrigation" are historic labels relating to the administration of shortage within the Indian Priority pool and do not represent type of use restrictions where Federal law provides otherwise.

contained within the Excel workbooks of the Priority Shortage Allocation Model. These formulas yield the distribution of available Indian Priority water shown in **Table C-12** below for a range of discrete Available CAP Supplies.

Table C-12
Distribution of CAP Indian Priority Supply

	Post-AWSA Contracts						Pre-AWSA Contracts									
Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	Distribution to Contractors (af)				Indian Priority Share	Indian Priority Supply (af)	Distribution to Contractors (af)							
			Gila River Indian Community	Tohono O'odham Nation (SX & ST)	White Mountain Apache Tribe	Scottsdale (Yavapai Prescott Indian Tribe)			Ak-Chin Indian Community	Fort McDowell Yavapai Nation	Pascua Yaqui Tribe	San Carlos Apache Tribe	Salt River Pima-Maricopa Indian Community	Sif Oidak District	Tonto Apache Tribe	Yavapai Apache Nation
990,000	Full Supply	343,079	191,200	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
981,902	Formula	343,079	191,200	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
980,000	Formula	342,595	190,716	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
970,000	Formula	340,051	188,172	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
960,000	Formula	337,508	185,629	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
950,000	Formula	334,964	183,085	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
940,000	Formula	332,420	180,541	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
930,000	Formula	329,876	177,997	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
920,000	Formula	327,332	175,453	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
910,000	Formula	324,789	172,910	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
900,000	Formula	322,245	170,366	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
890,000	Formula	319,701	167,822	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
880,000	Formula	317,157	165,278	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
870,000	Formula	314,613	162,734	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
860,000	Formula	312,070	160,191	37,800	1,218	500	Full Supply	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
853,079	36.37518%	310,309	158,430	37,800	1,218	500	Imputed	343,079	58,300	18,233	500	12,700	13,300	8,000	128	1,200
850,000	36.37518%	309,189	157,802	37,800	1,218	500	Imputed	340,000	57,951	18,233	500	12,684	13,220	7,952	128	1,200
840,000	36.37518%	305,552	155,762	37,800	1,218	500	Imputed	330,000	56,820	18,233	500	12,631	12,962	7,797	128	1,200
830,000	36.37518%	301,914	153,723	37,800	1,218	500	Imputed	320,000	55,688	18,233	500	12,579	12,704	7,642	128	1,200
820,000	36.37518%	298,276	151,683	37,800	1,218	500	Imputed	310,000	54,556	18,233	500	12,527	12,446	7,486	128	1,200
819,828	36.37518%	298,214	151,648	37,800	1,218	500	Imputed	309,828	54,536	18,233	500	12,526	12,441	7,484	128	1,200
810,000	36.37518%	294,639	149,644	37,800	1,218	500	Imputed	300,000	53,424	18,233	500	12,474	12,188	7,331	128	1,200
801,574	36.37518%	291,574	147,925	37,800	1,218	500	Either	291,574	52,470	18,233	500	12,430	11,970	7,200	128	1,200
800,000	36.37518%	291,001	147,635	37,726	1,216	499	36.37518%	291,001	52,367	18,197	499	12,406	11,946	7,186	128	1,198
790,000	36.37518%	287,364	145,789	37,254	1,200	493	36.37518%	287,364	51,712	17,970	493	12,251	11,797	7,096	126	1,183
780,000	36.37518%	283,726	143,944	36,783	1,185	487	36.37518%	283,726	51,058	17,742	487	12,095	11,648	7,006	125	1,168
770,000	36.37518%	280,089	142,098	36,311	1,170	480	36.37518%	280,089	50,403	17,515	480	11,940	11,499	6,916	123	1,153
760,000	36.37518%	276,451	140,253	35,839	1,155	474	36.37518%	276,451	49,749	17,287	474	11,785	11,349	6,827	121	1,138
750,000	36.37518%	272,814	138,407	35,368	1,140	468	36.37518%	272,814	49,094	17,060	468	11,630	11,200	6,737	120	1,123
740,000	36.37518%	269,176	136,562	34,896	1,124	462	36.37518%	269,176	48,439	16,832	462	11,475	11,051	6,647	118	1,108
730,000	36.37518%	265,539	134,717	34,425	1,109	455	36.37518%	265,539	47,785	16,605	455	11,320	10,901	6,557	117	1,093
720,000	36.37518%	261,901	132,871	33,953	1,094	449	36.37518%	261,901	47,130	16,377	449	11,165	10,752	6,467	115	1,078
710,000	36.37518%	258,264	131,026	33,482	1,079	443	36.37518%	258,264	46,476	16,150	443	11,010	10,603	6,377	113	1,063

	Post-AWSA Contracts						Pre-AWSA Contracts								
			Distribution to Contractors (af)						Distribution to Contractors (af)							
Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	Gila River Indian Community	Tohono O'odham Nation (SX & ST)	White Mountain Apache Tribe	Scottsdale (Yavapai Prescott Indian Tribe)	Indian Priority Share	Indian Priority Supply (af)	Ak-Chin Indian Community	Fort McDowell Yavapai Nation	Pascua Yaqui Tribe	San Carlos Apache Tribe	Salt River Pima-Maricopa Indian Community	Sif Oidak District	Tonto Apache Tribe	Yavapai Apache Nation
700,000	36.37518%	254,626	129,180	33,010	1,064	437	36.37518%	254,626	45,821	15,923	437	10,855	10,453	6,288	112	1,048
690,000	36.37518%	250,989	127,335	32,538	1,048	430	36.37518%	250,989	45,167	15,695	430	10,700	10,304	6,198	110	1,033
680,000	36.37518%	247,351	125,489	32,067	1,033	424	36.37518%	247,351	44,512	15,468	424	10,545	10,155	6,108	109	1,018
670,000	36.37518%	243,714	123,644	31,595	1,018	418	36.37518%	243,714	43,857	15,240	418	10,390	10,005	6,018	107	1,003
660,000	36.37518%	240,076	121,798	31,124	1,003	412	36.37518%	240,076	43,203	15,013	412	10,235	9,856	5,928	105	988
650,000	36.37518%	236,439	119,953	30,652	988	405	36.37518%	236,439	42,548	14,785	405	10,080	9,707	5,839	104	973
640,000	36.37518%	232,801	118,108	30,181	972	399	36.37518%	232,801	41,894	14,558	399	9,924	9,557	5,749	102	958
630,000	36.37518%	229,164	116,262	29,709	957	393	36.37518%	229,164	41,239	14,330	393	9,769	9,408	5,659	101	943
620,000	36.37518%	225,526	114,417	29,237	942	387	36.37518%	225,526	40,584	14,103	387	9,614	9,259	5,569	99	928
610,000	36.37518%	221,889	112,571	28,766	927	381	36.37518%	221,889	39,930	13,875	381	9,459	9,109	5,479	97	913
600,000	36.37518%	218,251	110,726	28,294	912	374	36.37518%	218,251	39,275	13,648	374	9,304	8,960	5,389	96	898
590,000	36.37518%	214,614	108,880	27,823	897	368	36.37518%	214,614	38,621	13,420	368	9,149	8,811	5,300	94	883
580,000	36.37518%	210,976	107,035	27,351	881	362	36.37518%	210,976	37,966	13,193	362	8,994	8,661	5,210	93	868
570,000	36.37518%	207,339	105,190	26,880	866	356	36.37518%	207,339	37,311	12,966	356	8,839	8,512	5,120	91	853
560,000	36.37518%	203,701	103,344	26,408	851	349	36.37518%	203,701	36,657	12,738	349	8,684	8,363	5,030	89	838
550,000	36.37518%	200,064	101,499	25,936	836	343	36.37518%	200,064	36,002	12,511	343	8,529	8,213	4,940	88	823
540,000	36.37518%	196,426	99,653	25,465	821	337	36.37518%	196,426	35,348	12,283	337	8,374	8,064	4,850	86	808
530,000	36.37518%	192,788	97,808	24,993	805	331	36.37518%	192,788	34,693	12,056	331	8,219	7,915	4,761	85	793
520,000	36.37518%	189,151	95,962	24,522	790	324	36.37518%	189,151	34,039	11,828	324	8,064	7,765	4,671	83	778
510,000	36.37518%	185,513	94,117	24,050	775	318	36.37518%	185,513	33,384	11,601	318	7,909	7,616	4,581	81	763
500,000	36.37518%	181,876	92,272	23,579	760	312	36.37518%	181,876	32,729	11,373	312	7,753	7,467	4,491	80	749
490,000	36.37518%	178,238	90,426	23,107	745	306	36.37518%	178,238	32,075	11,146	306	7,598	7,317	4,401	78	734
480,000	36.37518%	174,601	88,581	22,635	729	299	36.37518%	174,601	31,420	10,918	299	7,443	7,168	4,312	77	719
470,000	36.37518%	170,963	86,735	22,164	714	293	36.37518%	170,963	30,766	10,691	293	7,288	7,019	4,222	75	704
460,000	36.37518%	167,326	84,890	21,692	699	287	36.37518%	167,326	30,111	10,463	287	7,133	6,869	4,132	73	689
450,000	36.37518%	163,688	83,044	21,221	684	281	36.37518%	163,688	29,456	10,236	281	6,978	6,720	4,042	72	674
440,000	36.37518%	160,051	81,199	20,749	669	274	36.37518%	160,051	28,802	10,008	274	6,823	6,571	3,952	70	659
430,000	36.37518%	156,413	79,354	20,278	653	268	36.37518%	156,413	28,147	9,781	268	6,668	6,421	3,862	69	644
420,000	36.37518%	152,776	77,508	19,806	638	262	36.37518%	152,776	27,493	9,554	262	6,513	6,272	3,773	67	629
410,000	36.37518%	149,138	75,663	19,334	623	256	36.37518%	149,138	26,838	9,326	256	6,358	6,123	3,683	65	614
400,000	36.37518%	145,501	73,817	18,863	608	250	36.37518%	145,501	26,183	9,099	250	6,203	5,973	3,593	64	599
390,000	36.37518%	141,863	71,972	18,391	593	243	36.37518%	141,863	25,529	8,871	243	6,048	5,824	3,503	62	584
380,000	36.37518%	138,226	70,126	17,920	577	237	36.37518%	138,226	24,874	8,644	237	5,893	5,675	3,413	61	569
370,000	36.37518%	134,588	68,281	17,448	562	231	36.37518%	134,588	24,220	8,416	231	5,738	5,525	3,323	59	554
360,000	36.37518%	130,951	66,436	16,977	547	225	36.37518%	130,951	23,565	8,189	225	5,583	5,376	3,234	57	539
350,000	36.37518%	127,313	64,590	16,505	532	218	36.37518%	127,313	22,911	7,961	218	5,427	5,227	3,144	56	524
340,000	36.37518%	123,676	62,745	16,033	517	212	36.37518%	123,676	22,256	7,734	212	5,272	5,077	3,054	54	509
330,000	36.37518%	120,038	60,899	15,562	501	206	36.37518%	120,038	21,601	7,506	206	5,117	4,928	2,964	53	494
320,000	36.37518%	116,401	59,054	15,090	486	200	36.37518%	116,401	20,947	7,279	200	4,962	4,779	2,874	51	479

	Post-AWSA Contracts						Pre-AWSA Contracts								
			Distribution to Contractors (af)						Distribution to Contractors (af)							
Available CAP Supply (af)	Indian Priority Share	Indian Priority Supply (af)	Gila River Indian Community	Tohono O'odham Nation (SX & ST)	White Mountain Apache Tribe	Scottsdale (Yavapai Prescott Indian Tribe)	Indian Priority Share	Indian Priority Supply (af)	Ak-Chin Indian Community	Fort McDowell Yavapai Nation	Pascua Yaqui Tribe	San Carlos Apache Tribe	Salt River Pima-Maricopa Indian Community	Sif Oidak District	Tonto Apache Tribe	Yavapai Apache Nation
310,000	36.37518%	112,763	57,208	14,619	471	193	36.37518%	112,763	20,292	7,051	193	4,807	4,629	2,785	50	464
300,000	36.37518%	109,126	55,363	14,147	456	187	36.37518%	109,126	19,638	6,824	187	4,652	4,480	2,695	48	449
290,000	36.37518%	105,488	53,518	13,676	441	181	36.37518%	105,488	18,983	6,596	181	4,497	4,331	2,605	46	434
280,000	36.37518%	101,851	51,672	13,204	425	175	36.37518%	101,851	18,328	6,369	175	4,342	4,181	2,515	45	419
270,000	36.37518%	98,213	49,827	12,732	410	168	36.37518%	98,213	17,674	6,142	168	4,187	4,032	2,425	43	404
260,000	36.37518%	94,575	47,981	12,261	395	162	36.37518%	94,575	17,019	5,914	162	4,032	3,883	2,335	42	389
250,000	36.37518%	90,938	46,136	11,789	380	156	36.37518%	90,938	16,365	5,687	156	3,877	3,733	2,246	40	374
240,000	36.37518%	87,300	44,290	11,318	365	150	36.37518%	87,300	15,710	5,459	150	3,722	3,584	2,156	38	359
230,000	36.37518%	83,663	42,445	10,846	349	143	36.37518%	83,663	15,056	5,232	143	3,567	3,435	2,066	37	344
220,000	36.37518%	80,025	40,599	10,375	334	137	36.37518%	80,025	14,401	5,004	137	3,412	3,285	1,976	35	329
210,000	36.37518%	76,388	38,754	9,903	319	131	36.37518%	76,388	13,746	4,777	131	3,256	3,136	1,886	34	314
200,000	36.37518%	72,750	36,909	9,431	304	125	36.37518%	72,750	13,092	4,549	125	3,101	2,987	1,796	32	299
190,000	36.37518%	69,113	35,063	8,960	289	119	36.37518%	69,113	12,437	4,322	119	2,946	2,837	1,707	30	284
180,000	36.37518%	65,475	33,218	8,488	274	112	36.37518%	65,475	11,783	4,094	112	2,791	2,688	1,617	29	269
170,000	36.37518%	61,838	31,372	8,017	258	106	36.37518%	61,838	11,128	3,867	106	2,636	2,539	1,527	27	254
160,000	36.37518%	58,200	29,527	7,545	243	100	36.37518%	58,200	10,473	3,639	100	2,481	2,389	1,437	26	240
150,000	36.37518%	54,563	27,681	7,074	228	94	36.37518%	54,563	9,819	3,412	94	2,326	2,240	1,347	24	225
140,000	36.37518%	50,925	25,836	6,602	213	87	36.37518%	50,925	9,164	3,185	87	2,171	2,091	1,258	22	210
130,000	36.37518%	47,288	23,991	6,130	198	81	36.37518%	47,288	8,510	2,957	81	2,016	1,941	1,168	21	195
120,000	36.37518%	43,650	22,145	5,659	182	75	36.37518%	43,650	7,855	2,730	75	1,861	1,792	1,078	19	180
110,000	36.37518%	40,013	20,300	5,187	167	69	36.37518%	40,013	7,200	2,502	69	1,706	1,643	988	18	165
100,000	36.37518%	36,375	18,454	4,716	152	62	36.37518%	36,375	6,546	2,275	62	1,551	1,493	898	16	150
90,000	36.37518%	32,738	16,609	4,244	137	56	36.37518%	32,738	5,891	2,047	56	1,396	1,344	808	14	135
80,000	36.37518%	29,100	14,763	3,773	122	50	36.37518%	29,100	5,237	1,820	50	1,241	1,195	719	13	120
70,000	36.37518%	25,463	12,918	3,301	106	44	36.37518%	25,463	4,582	1,592	44	1,085	1,045	629	11	105
60,000	36.37518%	21,825	11,073	2,829	91	37	36.37518%	21,825	3,928	1,365	37	930	896	539	10	90
50,000	36.37518%	18,188	9,227	2,358	76	31	36.37518%	18,188	3,273	1,137	31	775	747	449	8	75
40,000	36.37518%	14,550	7,382	1,886	61	25	36.37518%	14,550	2,618	910	25	620	597	359	6	60
30,000	36.37518%	10,913	5,536	1,415	46	19	36.37518%	10,913	1,964	682	19	465	448	269	5	45
20,000	36.37518%	7,275	3,691	943	30	12	36.37518%	7,275	1,309	455	12	310	299	180	3	30
10,000	36.37518%	3,638	1,845	472	15	6	36.37518%	3,638	655	227	6	155	149	90	2	15
-	36.37518%	-	-	-	-	-	36.37518%	-	-	-	-	-	-	-	-	-

CAP M&I Priority Assumptions

The M&I Priority supply is calculated as the remainder of Available CAP Supply (up to 981,902 af) after the Indian Priority supply is calculated. When Available CAP Supply equals or exceeds 981,902 af, the Indian and M&I Priorities both receive a full supply.

The available M&I Priority supply is distributed to each allocation proportionally, relative to all allocations of M&I Priority water. [22] (The proportions are shown below in **Table C-13**).

Table C-13
Distribution of CAP M&I Priority Water in Proportion to Allocations

M&I Contractor or Subcontractor	Allocation (af)	Percentage of M&I Allocations
San Carlos Apache Tribe	18,145	2.84%
ASARCO	21,000	3.29%
Avondale	5,416	0.85%
AZSLD	28,176	4.41%
AZWC, Casa Grande	8,884	1.39%
AZWC, Coolidge	2,000	0.31%
AZWC, Superstition	6,285	0.98%
AZWC, White Tank	968	0.15%
Buckeye	68	0.01%
CAGRD	6,426	1.01%
Carefree WC	1,678	0.26%
Cave Creek	2,228	0.35%
Chandler	8,654	1.35%
Chaparral City WC	8,909	1.39%
Circle City	3,932	0.62%
El Mirage	508	0.08%
Eloy	2,171	0.34%
EPCOR, af	11,093	1.74%
EPCOR, PV	3,231	0.51%
EPCOR, SC	4,189	0.66%
EPCOR, SCW	2,372	0.37%
Florence	2,048	0.32%
Freeport-Miami	2,906	0.45%
FWID	2,854	0.45%
Gilbert	7,235	1.13%
Glendale	17,236	2.70%
Goodyear	10,742	1.68%
Greater Tonopah, Water Utility	64	0.01%
Green Valley CWC	2,858	0.45%
Green Valley DWID	1,900	0.30%
Marana	2,336	0.37%

[22] As a result of a joint consultation undertaken by Reclamation and the Central Arizona Water Conservation District with M&I Priority water users in 2022, documented by Letter Agreement No. 22-XX-30-W0743LA between Reclamation and Central Arizona Water Conservation District, dated May 15, 2023, the operational method of distributing M&I Priority water is a pro rata distribution on the basis of water scheduled for delivery. The results are currently consistent for most water users, and are expected to become more consistent over the long term.

M&I Contractor or Subcontractor	Allocation (af)	Percentage of M&I Allocations
Maricopa Cty P&R	665	0.10%
Mesa	43,503	6.81%
Metro DWID	13,460	2.11%
Oro Valley	10,305	1.61%
Peoria	27,121	4.25%
Phoenix	126,104	19.74%
Pine	161	0.03%
Queen Creek	495	0.08%
Rio Verde Utilities	812	0.13%
San Tan ID	236	0.04%
Scottsdale	52,810	8.27%
Spanish Trail WC	3,037	0.48%
Surprise	10,249	1.60%
Tempe	4,315	0.68%
Tonto Hills DWID	71	0.01%
Tucson	144,191	22.57%
Vail WC	1,857	0.29%
WUCFD, Apache Junction	2,919	0.46%
TOTAL	**638,823**	**100.00%**

CAP NIA Priority Assumptions

Only when Available CAP Supply is calculated to be greater than 981,902 af, the NIA Priority supply is calculated as the difference between Available CAP Supply and the sum of the Indian and M&I Priority entitlements. NIA Priority supply is assumed not to be available when Available CAP Supply is less than 981,902 af.

The Shortage Allocation Model does not contain data for CAP water use in the most recent year that a full NIA Priority supply (inclusive of NIA-A and NIA-B) was available. However, in this modeling, available water is distributed first to NIA Priority contractors and subcontractors assumed to have used CAP NIA Priority Water in the last year in which the Available CAP Supply was sufficient to fill all orders for CAP NIA Priority Water (NIA-A) (**Table C-14**), before available water is distributed to the other NIA Priority contracts and subcontracts (NIA-B) (**Table C-15**).[23] Within each sub-priority, available water is modeled as being distributed to each allocation proportionally, relative to total allocations for the sub-priority.

[23] The CAP NIA Priority Water is distributed in accordance with the CAP NIA Priority Water subcontracts, in particular paragraph 4.7(b)-(c) of such subcontracts, and the settlement agreements with the Gila River Indian Community and the Tohono O'odham Nation. The Hualapai Tribe's CAP NIA Priority water will be distributed in accordance with its settlement agreement (pending enforceability) and the Hualapai Tribe Water Rights Settlement Act of 2022, in particular section 13. In continuing to model the existence of separate NIA-A and NIA-B priority pools, no opinion is expressed or implied by the U.S. about the likelihood of a future year in which Available CAP Supply will be sufficient to fill all orders for CAP NIA Priority Water.

Table C-14
Distribution of CAP NIA-A Priority Water in Proportion to Allocations

NIA A Priority Contractor or Subcontractor	Allocation (af)	Percentage of NIA-A Allocations
Gila River Indian Community	120,600	58.80%
Tohono O'odham - Schuk Toak & San Xavier	28,200	13.75%
Hualapai Tribe	4,000	1.95%
Phoenix (HIDD, NIA-2043)	36,144	17.62%
Phoenix (SRPMIC)	1,136	0.55%
Chandler (HIDD, NIA-2043)	2,952	1.44%
Chandler (SRPMIC)	972	0.47%
Gilbert (SRPMIC)	1,537	0.75%
Glendale (SRPMIC)	682	0.33%
Mesa (HIDD, NIA-2043)	4,924	2.40%
Mesa (SRPMIC)	627	0.31%
Scottsdale (HIDD, NIA-2043)	3,283	1.60%
Scottsdale (SRPMIC)	23	0.01%
Tempe (SRPMIC)	23	0.01%
TOTAL	**205,103**	**100.00%**

Table C-15
Distribution of CAP NIA-B Priority Water in Proportion to Allocations

NIA B Priority Contractor or Subcontractor	Allocation (af)	Percentage of NIA-B Allocations
White Mountain Apache Tribe	23,782	34.81%
Buckeye	2,786	4.08%
CAGRD	18,185	26.62%
Carefree WC	112	0.16%
Cave Creek	386	0.57%
El Mirage	1,318	1.93%
EPCOR, San Tan (ST)	3,217	4.71%
Freeport	5,678	8.31%
Gilbert	1,832	2.68%
Marana	515	0.75%
Queen Creek	4,162	6.09%
Resolution Copper	2,238	3.28%
Rosemont Copper	1,124	1.65%
SRP	2,160	3.16%
WUCFD, Apache Junction	817	1.20%
TOTAL	**68,312**	**100.00%**

C.4.4 Priority Shortage Allocation Model Results

The tables in this section present the results of the Priority Shortage Allocation Model over a range of total shortages to the Lower Basin including Mexico.

Table C-16, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-17, the Tribal Summary, presents the shortage impacts on tribes.

Table C-18, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-19, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-16
Priority Shortage Allocation Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
Arizona	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion	449,422	728,066	1,076,371	1,285,355	1,295,172	1,295,540	1,295,172	1,295,172	1,295,172	1,295,172	1,295,172
-	NIA Priority[2]	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415
-	M&I Priority[2]	141,599	318,886	540,495	638,823	638,823	638,823	638,823	638,823	638,823	638,823	638,823
-	Indian Priority[2]	58,810	160,167	286,864	343,079	343,079	343,079	343,079	343,079	343,079	343,079	343,079
-	4th Priority i (Mainstream)	14,986	45,946	84,647	107,867	108,958	108,958	108,958	108,958	108,958	108,958	108,958
-	2nd & 3rd Priorities	0	0	0	0	47,914	73,318	125,232	305,643	434,507	563,371	798,059
-	1st Priority (Present Perfected Rights)	0	0	0	0	0	0	0	0	0	0	54,153
-	**Subtotal**	**464,407**	**774,012**	**1,161,018**	**1,393,222**	**1,452,044**	**1,477,817**	**1,529,362**	**1,709,773**	**1,838,637**	**1,967,501**	**2,256,342**
California	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	0	0	0	0	95,981	147,609	250,866	388,002	388,002	388,002	388,002
-	3rd Priority (IID, CVWD, PVID)	0	0	0	0	0	0	0	224,262	482,404	740,546	835,000
-	2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0	0	0	0	0	0	7,294
-	1st Priority (PVID)	0	0	0	0	0	0	0	0	0	0	368,378
-	Present Perfected Rights (PPRs)	0	0	0	0	0	0	0	0	0	0	20,049
-	**Subtotal**	**0**	**0**	**0**	**0**	**95,981**	**147,609**	**250,866**	**612,264**	**870,406**	**1,128,547**	**1,618,723**
Nevada	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	35,593	59,321	88,982	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717
-	8th Priority (SNWA & Big Bend)	0	0	0	14,061	25,926	31,858	43,722	85,247	114,907	144,568	162,980
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	0	0	0	0	0	0	0	0	0	0	2,257
-	6th Priority (Las Vegas Valley Water District)	0	0	0	0	0	0	0	0	0	0	8,012
-	5th Priority (PABCO)	0	0	0	0	0	0	0	0	0	0	483
-	4th Priority (Henderson & Basic)	0	0	0	0	0	0	0	0	0	0	20,299
-	3rd Priority (Boulder City)	0	0	0	0	0	0	0	0	0	0	3,056
-	2nd Priority (Lake Mead National Rec Area)	0	0	0	0	0	0	0	0	0	0	1,500
-	1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	0	0	0	0	0	0	0	0	0	0	300
-	**Subtotal**	**35,593**	**59,321**	**88,982**	**106,778**	**118,642**	**124,574**	**136,439**	**177,963**	**207,624**	**237,285**	**291,602**
-	**Lower Division States Subtotal**	**500,000**	**833,333**	**1,250,000**	**1,500,000**	**1,666,667**	**1,750,000**	**1,916,667**	**2,500,000**	**2,916,667**	**3,333,333**	**4,166,667**
Mexico	**Mexico Subtotal**	**100,000**	**166,667**	**250,000**	**300,000**	**333,333**	**350,000**	**383,333**	**500,000**	**583,333**	**666,667**	**833,333**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here.

[2]These estimated shortages to priorities within the CAP reflect the effect of CAP system loss, and do not total to CAP shortage at the point of diversion

Disclaimer: These modeling results for the Priority Shortage Allocation Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required for that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Note: Orange highlights indicate the level at which available water for a priority is reduced to zero.

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Table C-17
Priority Shortage Allocation Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona													
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	46,981	98,403	162,680	191,200	191,200	191,200	191,200	191,200	191,200	191,200	191,200
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	947	14,087	30,512	37,800	37,800	37,800	37,800	37,800	37,800	37,800	37,800
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	31	454	983	1,218	1,218	1,218	1,218	1,218	1,218	1,218	1,218
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	7,144	25,384	48,184	58,300	58,300	58,300	58,300	58,300	58,300	58,300	58,300
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	457	6,795	14,718	18,233	18,233	18,233	18,233	18,233	18,233	18,233	18,233
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	13	186	404	500	500	500	500	500	500	500	500
CAP Indian Priority	San Carlos Apache Tribe	Gila County	581	4,902	10,304	12,700	12,700	12,700	12,700	12,700	12,700	12,700	12,700
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	1,630	5,791	10,992	13,300	13,300	13,300	13,300	13,300	13,300	13,300	13,300
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	980	3,483	6,612	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
CAP Indian Priority	Tonto Apache Tribe	Gila County	3	48	103	128	128	128	128	128	128	128	128
CAP Indian Priority	Yavapai Apache Nation	Gila County	30	447	969	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
CAP M&I Priority	San Carlos Apache Tribe	Gila County	4,022	9,058	15,352	18,145	18,145	18,145	18,145	18,145	18,145	18,145	18,145
4(i)	Hopi Tribe[1]	La Paz County	389	1,194	2,199	2,803	2,831	2,831	2,831	2,831	2,831	2,831	2,831
4(i)	Cocopah Indian Reservation	Yuma County	184	565	1,042	1,327	1,341	1,341	1,341	1,341	1,341	1,341	1,341

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	319	977	1,799	2,293	2,316	2,316	2,316	2,316	2,316	2,316	2,316
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	931	2,855	5,259	6,702	6,770	6,770	6,770	6,770	6,770	6,770	6,770
3	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	1,340	4,802	16,922	25,578	34,235	50,000
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**241,224**	**351,211**	**488,694**	**550,431**	**550,563**	**551,903**	**555,366**	**567,485**	**576,142**	**584,798**	**600,563**
California			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**241,224**	**351,211**	**488,694**	**550,431**	**550,563**	**551,903**	**555,366**	**567,485**	**576,142**	**584,798**	**600,563**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	2,106	2,326	2,600	2,764	2,772	2,772	2,772	2,772	2,772	2,772	2,772
-	Gila County	-	12,574	22,533	34,983	40,506	40,506	40,506	40,506	40,506	40,506	40,506	40,506
-	La Paz County	-	389	1,194	2,199	2,803	2,831	2,831	2,831	2,831	2,831	2,831	2,831
-	Maricopa County	-	52,361	78,287	110,694	125,073	125,073	125,073	125,073	125,073	125,073	125,073	125,073
-	Mohave County	-	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
-	Pima County	-	29,159	42,473	59,116	66,500	66,500	66,500	66,500	66,500	66,500	66,500	66,500
-	Pinal County	-	125,431	182,169	253,092	284,560	284,560	285,900	289,362	301,482	310,138	318,795	334,560
-	Yuma County	-	1,115	3,420	6,301	8,029	8,110	8,110	8,110	8,110	8,110	8,110	8,110
-	Apache County	-	8,044	8,404	8,855	9,098	9,105	9,105	9,105	9,105	9,105	9,105	9,105
-	Navajo County	-	8,044	8,404	8,855	9,098	9,105	9,105	9,105	9,105	9,105	9,105	9,105
-	**Subtotal Arizona Tribal**	-	**241,224**	**351,211**	**488,694**	**550,431**	**550,563**	**551,903**	**555,366**	**567,485**	**576,142**	**584,798**	**600,563**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
-	Riverside	-	0	0	0	0	0	0	0	0	0	0	0
-	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and Tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Disclaimer: These modeling results for the Priority Shortage Allocation Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced to zero.

Table C-18
Priority Shortage Allocation Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	258	792	1,459	1,859	1,878	1,878	1,878	1,878	1,878	1,878	1,878
4(i)	Arizona State Land Department	Yuma County	601	1,844	3,397	4,328	4,372	4,372	4,372	4,372	4,372	4,372	4,372
4(i)	Beattie Farms, Southwest	Yuma County	101	310	571	727	735	735	735	735	735	735	735
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	38	117	216	275	278	278	278	278	278	278	278
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	11	35	65	83	83	83	83	83	83	83	83
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	191	586	1,080	1,376	1,390	1,390	1,390	1,390	1,390	1,390	1,390
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	20	60	111	142	143	143	143	143	143	143	143
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	677	2,077	3,826	4,876	4,925	4,925	4,925	4,925	4,925	4,925	4,925
4(i)	Curtis, Armon	Yuma County	27	84	154	197	199	199	199	199	199	199	199
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	131	400	738	940	950	950	950	950	950	950	950
4(i)	Matador Farms, LLC	La Paz County	410	1,256	2,313	2,948	2,978	2,978	2,978	2,978	2,978	2,978	2,978
4(i)	JRJ Partners, L.L.C.	Yuma County	98	301	555	708	715	715	715	715	715	715	715
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	3,191	9,784	18,024	22,969	23,201	23,201	23,201	23,201	23,201	23,201	23,201
4(i)	North Baja Pipeline, LLC[2]	La Paz County	44	134	247	314	318	318	318	318	318	318	318
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	84	258	475	605	611	611	611	611	611	611	611
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	44	134	247	314	318	318	318	318	318	318	318
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	44	136	250	318	322	322	322	322	322	322	322
4(i)	Red River Land Company, LLC	La Paz County	27	84	154	197	199	199	199	199	199	199	199

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Phillips, Milton and Jean	Yuma County	5	17	31	39	40	40	40	40	40	40	40
4(i)	Western Water, LLC	La Paz County	49	150	276	351	355	355	355	355	355	355	355
3	Sturges, Harold	Yuma County	0	0	0	0	0	335	335	335	335	335	335
3	Sturges, Irma	Yuma County	0	0	0	0	0	385	385	385	385	385	385
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	1,261	11,242	46,174	71,126	96,077	141,519
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	599	5,344	21,951	33,813	45,675	67,278
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	0	0	0	0	0	60	535	2,196	3,383	4,570	6,731
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	7,449	26,701	94,084	142,214	190,345	278,000
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	0	0	0	0	0	96	344	1,212	1,833	2,453	3,582
3	Yuma County Water Users' Association (14,701 af M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	0	0	0	0	0	1,981	7,483	26,741	40,497	54,252	79,304
3	University of Arizona	Yuma County	0	0	0	0	0	123	1,088	1,088	1,088	1,088	1,088
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	0	0	0	0	0	0	120	120	120	120	120
3	Unit B Irrigation & Drainage District[3]	Yuma County	0	0	0	0	0	0	305	4,751	7,927	11,102	16,886
1	PPR No. 15, Molina	Yuma County	0	0	0	0	0	0	0	0	0	0	318
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	0	0	0	0	0	0	0	0	0	0	445
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	0	0	0	0	0	0	0	0	0	0	4,352
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	0	0	0	0	0	0	0	0	0	0	6,125
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	0	0	0	0	0	0	0	0	0	0	42,914
1	PPR No. 7, Powers	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 10, Hulet (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 12, Miller (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 18, Swan (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**6,053**	**18,557**	**34,188**	**43,566**	**44,007**	**56,296**	**97,889**	**243,044**	**346,727**	**450,409**	**693,389**
California			**-**	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	0	0	0	0	0	0	0	1,343	2,889	4,434	5,000
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	0	0	0	0	0	0	0	222,919	330,000	330,000	330,000
3	Imperial Irrigation District (IID) (3a)	Imperial County	0	0	0	0	0	0	0	0	149,515	406,111	500,000
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	0	0	0	0	0	0	0	0	0	0	7,294
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	368,378
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	0	0	0	0	0	0	0	0	0	0	115
PPR	PPR No. 41, Chagnon	San Bernardino	0	0	0	0	0	0	0	0	0	0	77
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	0	0	0	0	0	0	0	0	0	0	61
PPR	PPR No. 34, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	69
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	0	0	0	0	0	0	0	0	0	0	19,518
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 42, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 37, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 33, Morgan	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 35, Simons	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**224,262**	**482,404**	**740,546**	**1,230,512**
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**6,053**	**18,557**	**34,188**	**43,566**	**44,007**	**56,296**	**97,889**	**467,306**	**829,131**	**1,190,955**	**1,923,901**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	1,534	4,705	8,667	11,045	11,156	11,156	11,156	11,156	11,156	11,156	11,156
-	Mohave County	-	3,191	9,784	18,024	22,969	23,201	23,201	23,201	23,201	23,201	23,201	23,201
-	Yuma County	-	1,327	4,069	7,497	9,553	9,650	21,938	63,531	208,687	312,370	416,052	659,032
-	**Subtotal Arizona Irrigation**	-	**6,053**	**18,557**	**34,188**	**43,566**	**44,007**	**56,296**	**97,889**	**243,044**	**346,727**	**450,409**	**693,389**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	0	0	0	0	0	0	0	224,262	332,889	334,434	519,189
-	Imperial County	-	0	0	0	0	0	0	0	0	149,515	406,111	711,185
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	138
-	**Subtotal California Irrigation**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**224,262**	**482,404**	**740,546**	**1,230,512**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement, which is not affected at these levels of shortages, and it was not included here.
Note: PPR entitlements are not affected at these levels of shortage.
Note: Orange highlights indicate the level at which available water for a user under this priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Disclaimer: These modeling results from the Shortage Allocation Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this Final EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and they are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required for that process.

Table C-19
Priority Shortage Allocation Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185
CAP NIA-B	Carefree Water Company	Maricopa County	112	112	112	112	112	112	112	112	112	112	112
CAP NIA-B	Cave Creek	Maricopa County	386	386	386	386	386	386	386	386	386	386	386
CAP NIA-B	El Mirage	Maricopa County	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217
CAP NIA-B	Freeport	Pima County	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678
CAP NIA-B	Gilbert	Maricopa County	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832
CAP NIA-B	Marana	Pima County	515	515	515	515	515	515	515	515	515	515	515
CAP NIA-B	Queen Creek	Maricopa County	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162
CAP NIA-B	Resolution Copper	Maricopa County	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238
CAP NIA-B	Rosemont Copper	Pima County	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124
CAP NIA-B	SRP	Maricopa County	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	817	817	817	817	817	817	817	817	817	817	817
CAP NIA-A	Phoenix	Maricopa County	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280
CAP NIA-A	Chandler	Maricopa County	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924
CAP NIA-A	Gilbert	Maricopa County	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537
CAP NIA-A	Glendale	Maricopa County	682	682	682	682	682	682	682	682	682	682	682
CAP NIA-A	Mesa	Maricopa County	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Scottsdale	Maricopa County	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306
CAP NIA-A	Tempe	Maricopa County	23	23	23	23	23	23	23	23	23	23	23
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	13	186	404	500	500	500	500	500	500	500	500
CAP M&I	ASARCO	Pima County	4,655	10,483	17,768	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000
CAP M&I	Avondale	Maricopa County	1,200	2,704	4,582	5,416	5,416	5,416	5,416	5,416	5,416	5,416	5,416
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	6,245	14,065	23,839	28,176	28,176	28,176	28,176	28,176	28,176	28,176	28,176
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	1,969	4,435	7,517	8,884	8,884	8,884	8,884	8,884	8,884	8,884	8,884
CAP M&I	Arizona Water Company, Coolidge	Pinal County	443	998	1,692	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
CAP M&I	Arizona Water Company, Superstition	Pinal County	1,393	3,137	5,318	6,285	6,285	6,285	6,285	6,285	6,285	6,285	6,285
CAP M&I	Arizona Water Company, White Tank	Maricopa County	215	483	819	968	968	968	968	968	968	968	968
CAP M&I	Buckeye	Maricopa County	15	34	58	68	68	68	68	68	68	68	68
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	1,424	3,208	5,437	6,426	6,426	6,426	6,426	6,426	6,426	6,426	6,426
CAP M&I	Carefree Water Company	Maricopa County	372	838	1,420	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678
CAP M&I	Cave Creek	Maricopa County	494	1,112	1,885	2,228	2,228	2,228	2,228	2,228	2,228	2,228	2,228
CAP M&I	Chandler	Maricopa County	1,918	4,320	7,322	8,654	8,654	8,654	8,654	8,654	8,654	8,654	8,654
CAP M&I	Chaparral City Water Company	Maricopa County	1,975	4,447	7,538	8,909	8,909	8,909	8,909	8,909	8,909	8,909	8,909
CAP M&I	Circle City	Maricopa County	872	1,963	3,327	3,932	3,932	3,932	3,932	3,932	3,932	3,932	3,932
CAP M&I	El Mirage	Maricopa County	113	254	430	508	508	508	508	508	508	508	508
CAP M&I	Eloy	Pinal County	481	1,084	1,837	2,171	2,171	2,171	2,171	2,171	2,171	2,171	2,171
CAP M&I	EPCOR, Agua Fria	Maricopa County	2,459	5,537	9,386	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093
CAP M&I	EPCOR, Paradise Valley	Maricopa County	716	1,613	2,734	3,231	3,231	3,231	3,231	3,231	3,231	3,231	3,231
CAP M&I	EPCOR, Sun City	Maricopa County	929	2,091	3,544	4,189	4,189	4,189	4,189	4,189	4,189	4,189	4,189

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	EPCOR, Sun City West	Maricopa County	526	1,184	2,007	2,372	2,372	2,372	2,372	2,372	2,372	2,372	2,372
CAP M&I	Florence	Pinal County	454	1,022	1,733	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048
CAP M&I	Freeport-Miami	Gila County	644	1,451	2,459	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	633	1,425	2,415	2,854	2,854	2,854	2,854	2,854	2,854	2,854	2,854
CAP M&I	Gilbert	Maricopa County	1,604	3,612	6,121	7,235	7,235	7,235	7,235	7,235	7,235	7,235	7,235
CAP M&I	Glendale	Maricopa County	3,820	8,604	14,583	17,236	17,236	17,236	17,236	17,236	17,236	17,236	17,236
CAP M&I	Goodyear	Maricopa County	2,381	5,362	9,089	10,742	10,742	10,742	10,742	10,742	10,742	10,742	10,742
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	14	32	54	64	64	64	64	64	64	64	64
CAP M&I	Green Valley Community Water Company	Pima County	633	1,427	2,418	2,858	2,858	2,858	2,858	2,858	2,858	2,858	2,858
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	421	948	1,608	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
CAP M&I	Marana	Pima County	518	1,166	1,976	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	147	332	563	665	665	665	665	665	665	665	665
CAP M&I	Mesa	Maricopa County	9,643	21,716	36,807	43,503	43,503	43,503	43,503	43,503	43,503	43,503	43,503
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	2,984	6,719	11,388	13,460	13,460	13,460	13,460	13,460	13,460	13,460	13,460
CAP M&I	Oro Valley	Pima County	2,284	5,144	8,719	10,305	10,305	10,305	10,305	10,305	10,305	10,305	10,305
CAP M&I	Peoria	Maricopa County	6,012	13,538	22,947	27,121	27,121	27,121	27,121	27,121	27,121	27,121	27,121
CAP M&I	Phoenix	Maricopa County	27,952	62,948	106,694	126,104	126,104	126,104	126,104	126,104	126,104	126,104	126,104
CAP M&I	Pine	Gila County	36	80	136	161	161	161	161	161	161	161	161
CAP M&I	Queen Creek	Maricopa County	110	247	419	495	495	495	495	495	495	495	495
CAP M&I	Rio Verde Utilities	Maricopa County	180	405	687	812	812	812	812	812	812	812	812
CAP M&I	San Tan Irrigation District	Maricopa County	52	118	200	236	236	236	236	236	236	236	236
CAP M&I	Scottsdale	Maricopa County	11,706	26,362	44,681	52,810	52,810	52,810	52,810	52,810	52,810	52,810	52,810
CAP M&I	Spanish Trail Water Company	Pima County	673	1,516	2,570	3,037	3,037	3,037	3,037	3,037	3,037	3,037	3,037

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Surprise	Maricopa County	2,272	5,116	8,671	10,249	10,249	10,249	10,249	10,249	10,249	10,249	10,249
CAP M&I	Tempe	Maricopa County	956	2,154	3,651	4,315	4,315	4,315	4,315	4,315	4,315	4,315	4,315
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	16	35	60	71	71	71	71	71	71	71	71
CAP M&I	Tucson	Pima County	31,961	71,977	121,997	144,191	144,191	144,191	144,191	144,191	144,191	144,191	144,191
CAP M&I	Vail Water Company	Pima County	412	927	1,571	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,857
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	647	1,457	2,470	2,919	2,919	2,919	2,919	2,919	2,919	2,919	2,919
4(i)	Arizona State Land Department	Yuma County	140	428	789	1,005	1,015	1,015	1,015	1,015	1,015	1,015	1,015
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	8	25	46	59	60	60	60	60	60	60	60
4(i)	B&F Investment, LLC	La Paz County	5	17	31	39	40	40	40	40	40	40	40
4(i)	Bullhead City	Mohave County	1,384	4,244	7,819	9,964	10,065	10,065	10,065	10,065	10,065	10,065	10,065
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	195	597	1,100	1,401	1,415	1,415	1,415	1,415	1,415	1,415	1,415
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	637	1,953	3,599	4,586	4,632	4,632	4,632	4,632	4,632	4,632	4,632
4(i)	Bureau of Land Management	La Paz County	561	1,721	3,171	4,041	4,082	4,082	4,082	4,082	4,082	4,082	4,082
4(i)	Crystal Beach Water Conservation District	Mohave County	12	37	68	86	87	87	87	87	87	87	87
4(i)	Ehrenburg Improvement District	La Paz County	67	205	378	482	486	486	486	486	486	486	486
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	171	523	963	1,228	1,240	1,240	1,240	1,240	1,240	1,240	1,240
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	5	15	27	35	35	35	35	35	35	35	35
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	1	1	1	1	1	1	1	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	1	2	4	5	5	5	5	5	5	5	5
4(i)	Golden Shores Water Conservation District	Mohave County	182	558	1,028	1,310	1,323	1,323	1,323	1,323	1,323	1,323	1,323
4(i)	GSC Farm, LLC	La Paz County	6	20	36	46	46	46	46	46	46	46	46
4(i)	Hillcrest Water Company	La Paz County	8	23	43	55	56	56	56	56	56	56	56
4(i)	Lake Havasu City	Mohave County	1,747	5,356	9,867	12,574	12,701	12,701	12,701	12,701	12,701	12,701	12,701

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	195	597	1,100	1,401	1,415	1,415	1,415	1,415	1,415	1,415	1,415
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	660	2,023	3,727	4,750	4,798	4,798	4,798	4,798	4,798	4,798	4,798
4(i)	La Paz County	La Paz County	32	98	180	229	232	232	232	232	232	232	232
4(i)	Martinez Lake Cabin Sites	Yuma County	2	6	12	15	15	15	15	15	15	15	15
4(i)	McAlister Family Trust	Mohave County	4	11	21	26	26	26	26	26	26	26	26
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	114	349	643	819	827	827	827	827	827	827	827
4(i)	Mohave Water Conservation District	Mohave County	164	502	925	1,179	1,191	1,191	1,191	1,191	1,191	1,191	1,191
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	273	837	1,542	1,965	1,985	1,985	1,985	1,985	1,985	1,985	1,985
4(i)	Parker, Town of[1]	La Paz County	94	287	530	675	682	682	682	682	682	682	682
4(i)	Quartzsite, Town of	La Paz County	97	299	550	701	708	708	708	708	708	708	708
4(i)	Queen Creek, Town of	Maricopa County	259	793	1,462	1,863	1,882	1,882	1,882	1,882	1,882	1,882	1,882
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	1	1	1	1	1	1	1	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	5	14	26	33	33	33	33	33	33	33	33
4(i)	Somerton, City of	Yuma County	68	209	386	491	496	496	496	496	496	496	496
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	9	28	51	66	66	66	66	66	66	66	66
4(i)	TV Marble Canyon AZ, LLC	Coconino County	6	20	36	46	46	46	46	46	46	46	46
3	City of Yuma[1]	Yuma County	0	0	0	0	43,258	48,522	48,522	48,522	48,522	48,522	48,522
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	0	0	0	0	0	25	25	25	25	25	25
3	Kaman, Inc.	Yuma County	0	0	0	0	0	2	2	2	2	2	2
3	Department of the Navy, MCAS	Yuma County	0	0	0	0	0	3,000	3,000	3,000	3,000	3,000	3,000
3	City of Yuma (cemetery)	Yuma County	0	0	0	0	0	60	60	60	60	60	60
3	Yuma Mesa Fruit Growers' Association	Yuma County	0	0	0	0	0	15	15	15	15	15	15

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Desert Lawn Memorial Park Association	Yuma County	0	0	0	0	0	138	138	138	138	138	138
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	115	411	1,448	2,188	2,929	4,278
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	181	649	2,288	3,459	4,630	6,762
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	80	288	1,015	1,535	2,054	3,000
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	74	265	934	1,412	1,890	2,760
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	134	480	1,692	2,558	3,423	5,000
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	3	10	34	51	68	100
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	3	10	34	51	68	100
3	Department of the Army - Yuma Proving Ground	Yuma County	0	0	0	0	0	30	108	382	578	773	1,129
3	Yuma Union High School District	Yuma County	0	0	0	0	0	148	148	148	148	148	148
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	0	0	0	0	0	0	248	248	248	248	248
2	Cibola National Wildlife Refuge	La Paz County	0	0	0	0	1,008	1,551	2,635	6,431	9,143	11,855	16,793
2	Lake Mead National Recreation Area	Mohave County	0	0	0	0	21	32	54	131	187	242	343
2	Bureau of Reclamation - Davis Dam	Mohave County	0	0	0	0	0	1	1	3	4	5	7
2	Imperial National Wildlife Refuge	La Paz County	0	0	0	0	1,381	2,124	3,609	8,809	12,522	16,236	23,000
2	Havasu Lake National Wildlife Refuge	Mohave County	0	0	0	0	2,245	3,453	5,869	14,323	20,362	26,401	37,399
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 20, Parker, City of	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 21, Yuma, City of	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**241,533**	**428,647**	**662,539**	**769,187**	**817,618**	**829,394**	**836,253**	**859,388**	**875,914**	**892,439**	**922,535**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	0	0	0	0	95,981	147,609	250,866	388,002	388,002	388,002	388,002
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 30, Stephenson	San Bernardino	0	0	0	0	0	0	0	0	0	0	154
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 38, Andrade	San Bernardino	0	0	0	0	0	0	0	0	0	0	42

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 39, Reynolds	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 43, City of Needles	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**95,981**	**147,609**	**250,866**	**388,002**	**388,002**	**388,002**	**388,210**
Nevada			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	35,593	59,321	88,982	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717
8	Big Bend Water District	Clark	0	0	0	423	779	958	1,315	2,563	3,455	4,346	4,900
8	Robert B. Griffith Project	Clark	0	0	0	13,639	25,146	30,900	42,408	82,684	111,453	140,222	158,080
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	0	0	0	0	0	0	0	0	0	5
7	Bureau of Reclamation (includes Sportsman Park)	Clark	0	0	0	0	0	0	0	0	0	0	147
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	0	0	0	0	0	0	0	0	0	0	25
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	0	0	0	0	0	0	0	0	0	0	2,080
6	Las Vegas Valley Water District	Clark	0	0	0	0	0	0	0	0	0	0	8,012
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	0	0	0	0	0	0	0	0	0	0	483
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	4,268
4	City of Henderson	Clark	0	0	0	0	0	0	0	0	0	0	8,257
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	7,774
3	Boulder City	Clark	0	0	0	0	0	0	0	0	0	0	3,056

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	0	0	0	0	0	0	0	0	0	0	1,500
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	0	0	0	0	0	0	0	0	0	0	300
-	-	**Subtotal**	**35,593**	**59,321**	**88,982**	**106,778**	**118,642**	**124,574**	**136,439**	**177,963**	**207,624**	**237,285**	**291,602**
-	-	**Total**	**277,126**	**487,968**	**751,521**	**875,965**	**1,032,241**	**1,101,578**	**1,223,557**	**1,425,354**	**1,471,539**	**1,517,725**	**1,602,347**
	Summary by County												
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	6	20	36	46	46	46	46	46	46	46	46.3223
-	Gila County	-	680	1,531	2,595	3,067	3,067	3,067	3,067	3,067	3,067	3,067	3,067
-	La Paz County	-	880	2,698	4,971	6,334	8,787	10,073	12,643	21,638	28,064	34,489	46,191
-	Maricopa County	-	172,090	280,895	416,901	477,351	477,370	477,959	479,483	484,815	488,624	492,433	499,370
-	Mohave County	-	5,745	17,613	32,448	41,349	44,034	45,253	47,691	56,225	62,320	68,415	79,516
-	Pima County	-	52,490	109,048	179,746	211,115	211,115	211,115	211,115	211,115	211,115	211,115	211,115
-	Pinal County	-	9,422	16,168	24,600	28,341	28,341	28,341	28,341	28,341	28,341	28,341	28,341
-	Yuma County	-	220	675	1,243	1,584	44,858	53,541	53,867	54,141	54,336	54,532	54,888
-	**Subtotal Arizona Domestic**	-	**241,533**	**428,647**	**662,539**	**769,187**	**817,618**	**829,394**	**836,253**	**859,388**	**875,914**	**892,439**	**922,535**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	0	0	0	0	95,981	147,609	250,866	388,002	388,002	388,002	388,002
-	Imperial County	-	0	0	0	0	0	0	0	0	0	0	11
-	Riverside County	-	0	0	0	0	0	0	0	0	0	0	1
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	196
-	**Subtotal California Domestic**	-	**0**	**0**	**0**	**0**	**95,981**	**147,609**	**250,866**	**388,002**	**388,002**	**388,002**	**388,210**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin by Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	35,593	59,321	88,982	106,778	118,642	124,574	136,439	177,963	207,624	237,285	291,602
-	**Subtotal Nevada Domestic**	-	**35,593**	**59,321**	**88,982**	**106,778**	**118,642**	**124,574**	**136,439**	**177,963**	**207,624**	**237,285**	**291,602**

[1]This user also holds a PPR entitlement.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Disclaimer: These modeling results from the Shortage Allocation Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and it cannot replicate the precision required for that process.

C.5 Continuing Current Strategies Shortage Allocation Model Assumptions

The Continuing Current Strategies Shortage Allocation Model describes the continued implementation of existing agreements that control operations of Glen Canyon and Hoover Dams. These include the 2007 Interim Guidelines and the 2019 DCP. The Continuing Current Strategies Shortage Allocation Model simulates shortages and distributes available water first among the Lower Division States based on the 2007 ROD and 2019 DCP and then among the entitlement holders within each state based on priority or as otherwise provided by the 2019 DCP.

The discrete volumes of total shortage to the Lower Division States considered in the Shortage Allocation Model comprise the 2007 Interim Guidelines shortage reductions and 2019 DCP water savings contributions, based on Lake Mead elevations.

This model exists as a comparative baseline, reflecting recent operations that water users in the Lower Basin are familiar with. The Excel workbook contains formulas to extend Continuing Current Strategies to deeper shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

For each level of modeled shortage that exceeds the shortages and contributions prescribed by the 2007 ROD and 2019 DCP, the Continuing Current Strategies Shortage Allocation Model calculates a percentage reduction to the Lower Division States and applies the same percentage reduction to Mexico's 1,500,000 acre-feet per year allotment.

C.5.1 Present Perfected Rights Assumptions for the Continuing Current Strategies Shortage Allocation Model

See **Section C.4.1** for a discussion on the PPR assumptions in the Priority Shortage Allocation Model. The Continuing Current Strategies Shortage Allocation Model has no unique assumptions with respect to PPRs.

C.5.2 Distribution Among States for the Continuing Current Strategies Shortage Allocation Model

The Continuing Current Strategies Shortage Allocation Model distributes shortages among states based on state reductions specified in the 2007 Interim Guidelines. This Shortage Allocation Model also simulates water savings contributions that were distributed among states as agreed to in the 2019 DCP. For the purpose of analyzing the impacts of alternatives considered in this EIS, DCP contributions are assumed to represent reductions in deliveries, although parties retain flexibility in how to meet those contribution commitments.

Table C-20 on the following page shows a distribution of shortage among the Lower Division States (which includes both 2007 Interim Guidelines shortages and 2019 DCP water savings contributions) and corresponding volumes of water available to each Lower Division State. Total shortage volumes include an assumed component for Mexico, as described in the sections that follow, and will not sum across rows.

Table C-20
Summary of Shortage Volumes and Available Water by Lower Division State Under the Continuing Current Strategies Shortage Allocation Model (af)

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
0	0	2,800,000	0	4,400,000	0	300,000
(241,000)	(192,000)	2,608,000	0	4,400,000	(8,000)	292,000
(613,000)	(512,000)	2,288,000	0	4,400,000	(21,000)	279,000
(721,000)	(592,000)	2,208,000	0	4,400,000	(25,000)	275,000
(1,013,000)	(640,000)	2,160,000	(200,000)	4,200,000	(27,000)	273,000
(1,071,000)	(640,000)	2,160,000	(250,000)	4,150,000	(27,000)	273,000
(1,129,000)	(640,000)	2,160,000	(300,000)	4,100,000	(27,000)	273,000
(1,188,000)	(640,000)	2,160,000	(350,000)	4,050,000	(27,000)	273,000
(1,375,000)	(720,000)	2,080,000	(350,000)	4,050,000	(30,000)	270,000
(1,440,000)	(811,267)	1,988,733	(350,000)	4,050,000	(38,733)	261,267
(1,500,000)	(856,901)	1,943,099	(350,000)	4,050,000	(43,099)	256,901
(1,680,000)	(993,801)	1,806,199	(350,000)	4,050,000	(56,199)	243,801
(1,800,000)	(1,085,068)	1,714,932	(350,000)	4,050,000	(64,932)	235,068
(1,920,000)	(1,176,336)	1,623,664	(350,000)	4,050,000	(73,664)	226,336
(2,000,000)	(1,237,180)	1,562,820	(350,000)	4,050,000	(79,486)	220,514
(2,100,000)	(1,313,236)	1,486,764	(350,000)	4,050,000	(86,764)	213,236
(2,160,000)	(1,358,870)	1,441,130	(350,000)	4,050,000	(91,130)	208,870
(2,219,509)	(1,404,130)	1,395,870	(350,000)	4,050,000	(95,461)	204,539
(2,280,000)	(1,422,069)	1,377,931	(378,068)	4,021,932	(99,863)	200,137
(2,300,000)	(1,428,000)	1,372,000	(387,348)	4,012,652	(101,319)	198,681
(2,400,000)	(1,457,656)	1,342,344	(433,748)	3,966,252	(108,596)	191,404
(2,520,000)	(1,493,242)	1,306,758	(489,429)	3,910,571	(117,329)	182,671
(2,640,000)	(1,528,829)	1,271,171	(545,109)	3,854,891	(126,062)	173,938
(2,760,000)	(1,564,416)	1,235,584	(600,790)	3,799,210	(134,795)	165,205
(2,880,000)	(1,600,003)	1,199,997	(656,470)	3,743,530	(143,527)	156,473
(3,000,000)	(1,635,589)	1,164,411	(712,150)	3,687,850	(152,260)	147,740
(3,120,000)	(1,671,176)	1,128,824	(767,831)	3,632,169	(160,993)	139,007
(3,240,000)	(1,706,763)	1,093,237	(823,511)	3,576,489	(169,726)	130,274
(3,360,000)	(1,742,350)	1,057,650	(879,191)	3,520,809	(178,459)	121,541
(3,480,000)	(1,777,936)	1,022,064	(934,872)	3,465,128	(187,192)	112,808

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(3,500,000)	(1,783,867)	1,016,133	(944,152)	3,455,848	(188,647)	111,353
(3,600,000)	(1,813,523)	986,477	(990,552)	3,409,448	(195,925)	104,075
(3,720,000)	(1,849,110)	950,890	(1,046,233)	3,353,767	(204,658)	95,342
(3,840,000)	(1,884,696)	915,304	(1,101,913)	3,298,087	(213,391)	86,609
(4,000,000)	(1,932,145)	867,855	(1,176,154)	3,223,846	(225,034)	74,966
(4,080,000)	(1,955,870)	844,130	(1,213,274)	3,186,726	(230,856)	69,144
(4,200,000)	(1,991,457)	808,543	(1,268,954)	3,131,046	(239,589)	60,411
(4,320,000)	(2,027,043)	772,957	(1,324,635)	3,075,365	(248,322)	51,678
(4,440,000)	(2,062,630)	737,370	(1,380,315)	3,019,685	(257,055)	42,945
(4,560,000)	(2,098,217)	701,783	(1,435,995)	2,964,005	(265,788)	34,212
(4,680,000)	(2,133,804)	666,196	(1,491,676)	2,908,324	(274,521)	25,479
(4,800,000)	(2,169,390)	630,610	(1,547,356)	2,852,644	(283,254)	16,746
(4,910,598)	(2,202,189)	597,811	(1,598,674)	2,801,326	(291,302)	8,698
(5,000,000)	(2,256,342)	543,658	(1,618,723)	2,781,277	(291,602)	8,398
(6,000,000)	(2,383,742)	416,258	(2,324,655)	2,075,345	(291,602)	8,398
(7,000,000)	(2,383,742)	416,258	(3,157,989)	1,242,011	(291,602)	8,398
(7,500,000)	(2,383,742)	416,258	(3,574,655)	825,345	(291,602)	8,398
(9,000,000)	(2,800,000)	0	(4,400,000)	0	(300,000)	0

The maximum shortage volume applied from the 2007 Interim Guidelines and 2019 DCP volumes to the Lower Division States is 1.1 maf, or 1.375 maf including Mexico.

C.5.2.1 Stage 1, 2, and 3 Shortage Assumptions

As in the Priority Shortage Allocation Model, the initial shortages to the Lower Division States are characterized by stages. In the Continuing Current Strategies Shortage Allocation Model, Stage 1 represented shortage volumes from the 2007 Interim Guidelines and the 2019 DCP. In the modeled Stage 2, additional shortages beyond Stage 1 are imposed only upon Arizona and Nevada and continue until the deliveries to the post-1968 water entitlement holders in Arizona (including the CAP) are reduced to zero. After deliveries to the fourth priority entitlements within Arizona are expected to be reduced to zero, any additional shortages are applied to Arizona, California, and Nevada in Stage 3. As with the Priority Shortage Allocation Model, the Continuing Current Strategies Shortage Allocation Model distributes shortage among the Lower Division States in a way that ensures PPRs can be satisfied (or reduced) in the prescribed order as a Basin-wide senior priority group. Instead of setting the entire volume of each state's apportionment as coequal to the others, only state apportionments in excess of PPRs are treated as coequal (but maintaining the assumption that Arizona bears California's share of shortage until the Arizona fourth priority is exhausted). In developing the Stage 2 and Stage 3 percentages for the sharing of shortage among the Lower Division States, the consumptive use (or equivalent) of PPR entitlements are removed from the apportionment volumes in each ratio, as detailed below.

The Stage 1 shortage volumes for the Continuing Current Strategies Shortage Allocation Model are fixed volumes and are shown above in **Table C-20**.

The Stage 2 shortage sharing percentages for the Continuing Current Strategies Shortage Allocation Model are computed as follows[24]:

- Nevada bears a reduction of about 9 percent of the total Lower Division States shortage volume, computed as a ratio of Nevada's apportionment less PPR consumptive use (or equivalent) entitlements within Nevada less the amount of shortage applied to Nevada under Stage 1, over the sum of the apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements less the total amount shorted to users under Stage 1
    - (300.0 kaf – NV PPRs – 30.0 kaf) / 7.5 maf – total PPRs – 1.1 maf) = 8.73 percent, or
        - (300.0 kaf – 8,698 af – 30.0 kaf) / (7.5 maf – 3,408,035 af – 1.1 maf) = 8.73 percent
- Arizona bears the remainder of the total Lower Division States shortage volume (approximately 91 percent), computed as a ratio of Arizona's and California's apportionments less PPR consumptive use (or equivalent) in both states less the amount of shortage applied to both states under Stage 1, over the sum of the apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements less the total amount shorted to users under Stage 1
    - (2.8 maf – AZ PPRs – 720 kaf + 4.4 maf – CA PPRs – 350 kaf) / (7.5 maf – total PPRs – 1.1 maf) = 91.27 percent, or
        - (2.8 maf – 597,811 af – 720 kaf + 4.4 maf – 2,801,326 af – 350 kaf) / (7.5 maf – 3,408,035 af – 1.1 maf) = 91.27 percent

As in the Priority Shortage Allocation Model, after deliveries to the fourth priority entitlements within Arizona are expected to be reduced to zero, any additional shortages are applied to Arizona, California, and Nevada. This Stage 3 shortage is the amount of additional shortage above the Stage 1 and Stage 2 shortage volumes, and the additional shortage is distributed according to the Stage 3 ratios.

The Stage 3 shortage sharing percentages are computed as follows, with the PPR volumes the same as in the Stage 2 ratios.

- Nevada bears about 9 percent of the Stage 3 shortage in addition to its Stage 1 and Stage 2 shortage, computed as a ratio of Nevada's apportionment less PPRs less the amount of

[24] Note that these ratios distribute shortage volumes, and the available water is calculated as a remainder.

shortage applied to Nevada under Stage 1 and 2, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1 and 2

- (300,000 – NV PPRs – Nevada Stage 1 and 2 shortage) / (7.5 maf – total PPRs – total Stage 1 and 2 shortage) = 8.73 percent, or
    - (300 kaf – 8,698 af – 95,461 af) / (7.5 maf – 3,407,835 af – 1,849,591 af) = 8.73 percent

- Arizona bears about 35.6 percent of the Stage 3 shortage in addition to its Stage 1 and 2 shortage, computed as a ratio of Arizona's apportionment less PPRs less the amount of shortage applied to Arizona under Stage 1 and 2, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1 and 2
    - (2.8 maf – AZ PPRs – Arizona Stage 1 and 2 shortage) / (7.5 maf – total PPRs – total Stage 1 and 2 shortage) = 35.59 percent, or
        - (2.8 maf – 597,811 af – 1,404,130 af) / (7.5 maf – 3,407,835 af – 1,849,591 af) = 35.59 percent

- California bears about 55.7 percent of the Stage 3 shortage, computed as a ratio of California's apportionment less PPRs less the amount of shortage applied to California under Stage 1, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to users under Stage 1 and 2
    - (4.4 maf – CA PPRs – California Stage 1 shortage) / (7.5 maf – total PPRs – total Stage 1 and 2 shortage) = 55.68 percent, or
        - (4.4 maf – 2,801,326 af – 350 kaf) / (7.5 maf – 3,407,835 af – 1,849,591 af) = 55.68 percent

This method represents one possible way to distribute deep shortages among the Lower Division States in a way that does not reduce PPR water deliveries in one state while fulfilling non-PPR water deliveries in another state.

C.5.3 Distribution Within States for the Continuing Current Strategies Shortage Allocation Model

C.5.3.1 Introduction

To estimate the impacts of given levels of shortage, assumptions were made with regard to how shortages might be shared. These assumptions are made to facilitate analysis of the potential impacts and they are not intended to represent current or future policy with respect to shortage allocation. The Continuing Current Strategies Shortage Allocation Model is not designed to replicate some of the annual processes that must be undertaken in determining the quantity of water that can be approved for diversion by specific users.

Modeling assumptions are consistent with the Priority Shortage Allocation Model unless described otherwise in the sections that follow.

C.5.3.2 General State Assumptions

For the purpose of analyzing the impacts of alternatives considered in this EIS, DCP contributions are assumed to represent reductions in deliveries, although parties retain flexibility in how to meet those contribution commitments.

C.5.3.3 Nevada Assumptions

The first 10 kaf shorted to Nevada is considered a DCP contribution. The Continuing Current Strategies Shortage Allocation Model does not treat Shortages and DCP contributions differently for the purpose of this EIS.

C.5.3.4 California Assumptions

The Shortage Allocation Model described in this Appendix E attributes 7 percent of California's DCP contributions to CVWD pursuant to the May 20, 2019, Drought Contingency Plan Implementation Agreement Between MWD and CVWD.

The first 325.5 kaf shorted to MWD is considered a DCP contribution, as is the first 24.5 kaf shorted to CVWD. The Continuing Current Strategies Shortage Allocation Model does not treat Shortages and DCP contributions differently for the purpose of this EIS.

C.5.3.5 Arizona Assumptions

The first 240 kaf shorted to Arizona is considered a DCP contribution. The Continuing Current Strategies Shortage Allocation Model does not treat Shortages and DCP contributions differently for the purpose of this EIS.

C.5.4 Continuing Current Strategies Shortage Allocation Model Results

The tables in this section present the results of the Continuing Current Strategies Shortage Allocation Model over a range of total shortages to the Lower Basin including Mexico.

Table C-21, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-22, the Tribal Summary, presents the shortage impacts on tribes.

Table C-23, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-24, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-21
Continuing Current Strategies Shortage Allocation Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies										
-	-	**613,000**	**1,013,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
Arizona	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion	492,255	607,455	802,666	1,008,017	1,144,917	1,213,368	1,295,172	1,295,172	1,295,172	1,295,172	1,295,172
-	NIA Priority[2]	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415
-	M&I Priority[2]	174,362	244,349	371,599	498,848	587,923	632,461	638,823	638,823	638,823	638,823	638,823
-	Indian Priority[2]	77,540	117,553	190,303	263,054	313,979	339,441	343,079	343,079	343,079	343,079	343,079
-	4th Priority i (Mainstream)	19,745	32,545	54,235	77,052	92,263	99,869	108,958	108,958	108,958	108,958	108,958
-	2nd & 3rd Priorities	0	0	0	0	0	0	23,870	231,459	379,737	528,015	798,059
-	1st Priority (Present Perfected Rights)	0	0	0	0	0	0	0	0	0	0	54,153
-	**Subtotal**	**512,000**	**640,000**	**856,901**	**1,085,068**	**1,237,180**	**1,313,236**	**1,428,000**	**1,635,589**	**1,783,867**	**1,932,145**	**2,256,342**
California	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	0	186,000	325,500	325,500	325,500	325,500	362,848	388,002	388,002	388,002	388,002
-	3rd Priority (IID, CVWD, PVID)	0	14,000	24,500	24,500	24,500	24,500	24,500	324,148	556,150	788,152	835,000
-	2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0	0	0	0	0	0	7,294
-	1st Priority (PVID)	0	0	0	0	0	0	0	0	0	0	368,378
-	Present Perfected Rights (PPRs)	0	0	0	0	0	0	0	0	0	0	20,049
-	**Subtotal**	**0**	**200,000**	**350,000**	**350,000**	**350,000**	**350,000**	**387,348**	**712,150**	**944,152**	**1,176,154**	**1,618,723**
Nevada	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	21,000	27,000	43,099	64,932	79,486	86,764	92,717	92,717	92,717	92,717	92,717
-	8th Priority (SNWA & Big Bend)	0	0	0	0	0	0	8,602	59,544	95,931	132,318	162,980
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	0	0	0	0	0	0	0	0	0	0	2,257
-	6th Priority (Las Vegas Valley Water District)	0	0	0	0	0	0	0	0	0	0	8,012
-	5th Priority (PABCO)	0	0	0	0	0	0	0	0	0	0	483

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies										
-	-	**613,000**	**1,013,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	4th Priority (Henderson & Basic)	0	0	0	0	0	0	0	0	0	0	20,299
-	3rd Priority (Boulder City)	0	0	0	0	0	0	0	0	0	0	3,056
-	2nd Priority (Lake Mead National Rec Area)	0	0	0	0	0	0	0	0	0	0	1,500
-	1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	0	0	0	0	0	0	0	0	0	0	300
-	**Subtotal**	**21,000**	**27,000**	**43,099**	**64,932**	**79,486**	**86,764**	**101,319**	**152,260**	**188,647**	**225,034**	**291,602**
-	**Lower Division States Subtotal**	**533,000**	**867,000**	**1,250,000**	**1,500,000**	**1,666,667**	**1,750,000**	**1,916,667**	**2,500,000**	**2,916,667**	**3,333,333**	**4,166,667**
Mexico	**Mexico Subtotal**	**80,000**	**146,000**	**250,000**	**300,000**	**333,333**	**350,000**	**383,333**	**500,000**	**583,333**	**666,667**	**833,333**
-	**Total**	**613,000**	**1,013,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

Disclaimer: These modeling results for the Continued Current Strategies Comparative Baseline should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here
[2]These estimated shortages to priorities within the CAP reflect the effect of CAP system loss, and do not total to CAP shortage at the point of diversion.

Table C-22
Continuing Current Strategies Shortage Allocation Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	56,483	76,783	113,692	150,601	176,437	189,355	191,200	191,200	191,200	191,200	191,200
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	3,375	8,563	17,994	27,425	34,027	37,328	37,800	37,800	37,800	37,800	37,800
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	109	276	580	884	1,096	1,203	1,218	1,218	1,218	1,218	1,218
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	10,515	17,716	30,807	43,899	53,063	57,645	58,300	58,300	58,300	58,300	58,300
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	1,628	4,130	8,679	13,229	16,413	18,006	18,233	18,233	18,233	18,233	18,233
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	45	113	238	363	450	494	500	500	500	500	500
CAP Indian Priority	San Carlos Apache Tribe	Gila County	1,380	3,086	6,187	9,288	11,459	12,545	12,700	12,700	12,700	12,700	12,700
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	2,399	4,041	7,028	10,015	12,105	13,151	13,300	13,300	13,300	13,300	13,300
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	1,443	2,431	4,227	6,024	7,281	7,910	8,000	8,000	8,000	8,000	8,000
CAP Indian Priority	Tonto Apache Tribe	Gila County	11	29	61	93	115	126	128	128	128	128	128
CAP Indian Priority	Yavapai Apache Nation	Gila County	107	272	571	871	1,080	1,185	1,200	1,200	1,200	1,200	1,200
CAP M&I Priority	San Carlos Apache Tribe	Gila County	4,953	6,940	10,555	14,169	16,699	17,964	18,145	18,145	18,145	18,145	18,145
4(i)	Hopi Tribe[1]	La Paz County	513	846	1,409	2,002	2,397	2,595	2,831	2,831	2,831	2,831	2,831
4(i)	Cocopah Indian Reservation	Yuma County	243	400	667	948	1,135	1,229	1,341	1,341	1,341	1,341	1,341
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	420	692	1,153	1,638	1,961	2,123	2,316	2,316	2,316	2,316	2,316
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	1,227	2,022	3,370	4,787	5,732	6,205	6,770	6,770	6,770	6,770	6,770

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	11,938	21,899	31,860	50,000
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**261,433**	**304,922**	**383,801**	**462,817**	**518,036**	**545,646**	**550,563**	**562,502**	**572,462**	**582,423**	**600,563**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**261,433**	**304,922**	**383,801**	**462,817**	**518,036**	**545,646**	**550,563**	**562,502**	**572,462**	**582,423**	**600,563**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies										
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	2,140	2,231	2,384	2,546	2,654	2,708	2,772	2,772	2,772	2,772	2,772
-	Gila County	-	14,415	18,346	25,495	32,643	37,647	40,149	40,506	40,506	40,506	40,506	40,506
-	La Paz County	-	513	846	1,409	2,002	2,397	2,595	2,831	2,831	2,831	2,831	2,831
-	Maricopa County	-	57,152	67,387	85,995	104,604	117,630	124,143	125,073	125,073	125,073	125,073	125,073
-	Mohave County	-	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
-	Pima County	-	31,620	36,876	46,432	55,988	62,678	66,022	66,500	66,500	66,500	66,500	66,500
-	Pinal County	-	135,916	158,315	199,039	239,763	268,270	282,524	284,560	296,498	306,459	316,420	334,560
-	Yuma County	-	1,470	2,423	4,037	5,735	6,868	7,434	8,110	8,110	8,110	8,110	8,110
-	Apache County	-	8,103	8,250	8,505	8,768	8,947	9,036	9,105	9,105	9,105	9,105	9,105
-	Navajo County	-	8,103	8,250	8,505	8,768	8,947	9,036	9,105	9,105	9,105	9,105	9,105
-	**Subtotal Arizona Tribal**	-	**261,433**	**304,922**	**383,801**	**462,817**	**518,036**	**545,646**	**550,563**	**562,502**	**572,462**	**582,423**	**600,563**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
-	Riverside	-	0	0	0	0	0	0	0	0	0	0	0
-	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Disclaimer: These modeling results for the Continued Current Strategies Comparative Baseline should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Table C-23
Continuing Current Strategies Shortage Allocation Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	340	561	935	1,328	1,590	1,721	1,878	1,878	1,878	1,878	1,878
4(i)	Arizona State Land Department	Yuma County	792	1,306	2,176	3,092	3,702	4,007	4,372	4,372	4,372	4,372	4,372
4(i)	Beattie Farms, Southwest	Yuma County	133	219	366	519	622	673	735	735	735	735	735
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	50	83	138	197	235	255	278	278	278	278	278
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	15	25	42	59	71	76	83	83	83	83	83
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	252	415	692	983	1,177	1,274	1,390	1,390	1,390	1,390	1,390
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	26	43	71	101	121	131	143	143	143	143	143
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	893	1,471	2,452	3,483	4,170	4,514	4,925	4,925	4,925	4,925	4,925
4(i)	Curtis, Armon	Yuma County	36	59	99	140	168	182	199	199	199	199	199
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	172	284	473	672	804	870	950	950	950	950	950
4(i)	Matador Farms, LLC	La Paz County	540	889	1,482	2,106	2,522	2,729	2,978	2,978	2,978	2,978	2,978
4(i)	JRJ Partners, L.L.C.	Yuma County	130	213	356	505	605	655	715	715	715	715	715
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	4,204	6,930	11,548	16,407	19,646	21,265	23,201	23,201	23,201	23,201	23,201
4(i)	North Baja Pipeline, LLC[2]	La Paz County	58	95	158	225	269	291	318	318	318	318	318
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	111	183	304	432	518	560	611	611	611	611	611
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	58	95	158	225	269	291	318	318	318	318	318
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	58	96	160	227	272	295	322	322	322	322	322
4(i)	Red River Land Company, LLC	La Paz County	36	59	99	140	168	182	199	199	199	199	199
4(i)	Phillips, Milton and Jean	Yuma County	7	12	20	28	34	36	40	40	40	40	40
4(i)	Western Water, LLC	La Paz County	64	106	177	251	301	325	355	355	355	355	355
3	Sturges, Harold	Yuma County	0	0	0	0	0	0	0	335	335	335	335
3	Sturges, Irma	Yuma County	0	0	0	0	0	0	0	385	385	385	385

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	31,810	60,521	89,231	141,519
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	15,122	28,771	42,420	67,278
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	0	0	0	0	0	0	0	1,513	2,879	4,244	6,731
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	66,376	121,758	177,139	278,000
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	0	0	0	0	0	0	0	855	1,569	2,283	3,582
3	Yuma County Water Users' Association (14,701 af M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	0	0	0	0	0	0	0	18,822	34,650	50,478	79,304
3	University of Arizona	Yuma County	0	0	0	0	0	0	0	1,088	1,088	1,088	1,088
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	0	0	0	0	0	0	0	120	120	120	120
3	Unit B Irrigation & Drainage District[3]	Yuma County	0	0	0	0	0	0	0	2,923	6,577	10,231	16,886
1	PPR No. 15, Molina	Yuma County	0	0	0	0	0	0	0	0	0	0	318
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	0	0	0	0	0	0	0	0	0	0	445
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	0	0	0	0	0	0	0	0	0	0	4,352
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	0	0	0	0	0	0	0	0	0	0	6,125
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	0	0	0	0	0	0	0	0	0	0	42,914
1	PPR No. 7, Powers	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 10, Hulet (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 12, Miller (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 18, Swan (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**7,975**	**13,145**	**21,905**	**31,120**	**37,264**	**40,336**	**44,007**	**183,357**	**302,660**	**421,963**	**693,389**
California			-	-	-	-	-	-	-	-		-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	0	0	0	0	0	0	147	1,941	3,330	4,719	5,000
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	0	14,000	24,500	24,500	24,500	24,500	24,353	322,207	330,000	330,000	330,000
3	Imperial Irrigation District (IID) (3a)	Imperial County	0	0	0	0	0	0	0	0	222,820	453,432	500,000
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	0	0	0	0	0	0	0	0	0	0	7,294
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	368,378
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	0	0	0	0	0	0	0	0	0	0	115
PPR	PPR No. 41, Chagnon	San Bernardino	0	0	0	0	0	0	0	0	0	0	77
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	0	0	0	0	0	0	0	0	0	0	61
PPR	PPR No. 34, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	69
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	0	0	0	0	0	0	0	0	0	0	19,518
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 42, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 37, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 33, Morgan	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 35, Simons	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**14,000**	**24,500**	**24,500**	**24,500**	**24,500**	**24,500**	**324,148**	**556,150**	**788,152**	**1,230,512**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-		-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**7,975**	**27,145**	**46,405**	**55,620**	**61,764**	**64,836**	**68,507**	**507,506**	**858,810**	**1,210,114**	**1,923,901**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	2,022	3,332	5,553	7,889	9,447	10,226	11,156	11,156	11,156	11,156	11,156
-	Mohave County	-	4,204	6,930	11,548	16,407	19,646	21,265	23,201	23,201	23,201	23,201	23,201
-	Yuma County	-	1,749	2,882	4,803	6,824	8,171	8,845	9,650	149,000	268,303	387,605	659,032
-	**Subtotal Arizona Irrigation**	-	**7,975**	**13,145**	**21,905**	**31,120**	**37,264**	**40,336**	**44,007**	**183,357**	**302,660**	**421,963**	**693,389**
-	**California**	-	-	-	-	-	-	-		-	-	-	-
-	Riverside County	-	0	14,000	24,500	24,500	24,500	24,500	24,500	324,148	333,330	334,719	519,189
-	Imperial County	-	0	0	0	0	0	0	0	0	222,820	453,432	711,185
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	138
-	**Subtotal California Irrigation**	-	**0**	**14,000**	**24,500**	**24,500**	**24,500**	**24,500**	**24,500**	**324,148**	**556,150**	**788,152**	**1,230,512**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

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Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Table C-24
Continuing Current Strategies Shortage Allocation Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185
CAP NIA-B	Carefree Water Company	Maricopa County	112	112	112	112	112	112	112	112	112	112	112
CAP NIA-B	Cave Creek	Maricopa County	386	386	386	386	386	386	386	386	386	386	386
CAP NIA-B	El Mirage	Maricopa County	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217
CAP NIA-B	Freeport	Pima County	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678
CAP NIA-B	Gilbert	Maricopa County	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832
CAP NIA-B	Marana	Pima County	515	515	515	515	515	515	515	515	515	515	515
CAP NIA-B	Queen Creek	Maricopa County	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162
CAP NIA-B	Resolution Copper	Maricopa County	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238
CAP NIA-B	Rosemont Copper	Pima County	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124
CAP NIA-B	SRP	Maricopa County	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	817	817	817	817	817	817	817	817	817	817	817
CAP NIA-A	Phoenix	Maricopa County	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280
CAP NIA-A	Chandler	Maricopa County	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924
CAP NIA-A	Gilbert	Maricopa County	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537
CAP NIA-A	Glendale	Maricopa County	682	682	682	682	682	682	682	682	682	682	682
CAP NIA-A	Mesa	Maricopa County	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551
CAP NIA-A	Scottsdale	Maricopa County	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306
CAP NIA-A	Tempe	Maricopa County	23	23	23	23	23	23	23	23	23	23	23
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	45	113	238	363	450	494	500	500	500	500	500
CAP M&I	ASARCO	Pima County	5,732	8,032	12,216	16,399	19,327	20,791	21,000	21,000	21,000	21,000	21,000
CAP M&I	Avondale	Maricopa County	1,478	2,072	3,150	4,229	4,984	5,362	5,416	5,416	5,416	5,416	5,416
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	7,690	10,777	16,390	22,002	25,931	27,895	28,176	28,176	28,176	28,176	28,176

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	2,425	3,398	5,168	6,937	8,176	8,796	8,884	8,884	8,884	8,884	8,884
CAP M&I	Arizona Water Company, Coolidge	Pinal County	546	765	1,163	1,562	1,841	1,980	2,000	2,000	2,000	2,000	2,000
CAP M&I	Arizona Water Company, Superstition	Pinal County	1,715	2,404	3,656	4,908	5,784	6,222	6,285	6,285	6,285	6,285	6,285
CAP M&I	Arizona Water Company, White Tank	Maricopa County	264	370	563	756	891	958	968	968	968	968	968
CAP M&I	Buckeye	Maricopa County	19	26	40	53	63	67	68	68	68	68	68
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	1,754	2,458	3,738	5,018	5,914	6,362	6,426	6,426	6,426	6,426	6,426
CAP M&I	Carefree Water Company	Maricopa County	458	642	976	1,310	1,544	1,661	1,678	1,678	1,678	1,678	1,678
CAP M&I	Cave Creek	Maricopa County	608	852	1,296	1,740	2,050	2,206	2,228	2,228	2,228	2,228	2,228
CAP M&I	Chandler	Maricopa County	2,362	3,310	5,034	6,758	7,964	8,568	8,654	8,654	8,654	8,654	8,654
CAP M&I	Chaparral City Water Company	Maricopa County	2,432	3,408	5,182	6,957	8,199	8,820	8,909	8,909	8,909	8,909	8,909
CAP M&I	Circle City	Maricopa County	1,073	1,504	2,287	3,070	3,619	3,893	3,932	3,932	3,932	3,932	3,932
CAP M&I	El Mirage	Maricopa County	139	194	295	397	468	503	508	508	508	508	508
CAP M&I	Eloy	Pinal County	593	830	1,263	1,695	1,998	2,149	2,171	2,171	2,171	2,171	2,171
CAP M&I	EPCOR, Agua Fria	Maricopa County	3,028	4,243	6,453	8,662	10,209	10,983	11,093	11,093	11,093	11,093	11,093
CAP M&I	EPCOR, Paradise Valley	Maricopa County	882	1,236	1,879	2,523	2,974	3,199	3,231	3,231	3,231	3,231	3,231
CAP M&I	EPCOR, Sun City	Maricopa County	1,143	1,602	2,437	3,271	3,855	4,147	4,189	4,189	4,189	4,189	4,189
CAP M&I	EPCOR, Sun City West	Maricopa County	647	907	1,380	1,852	2,183	2,348	2,372	2,372	2,372	2,372	2,372
CAP M&I	Florence	Pinal County	559	783	1,191	1,599	1,885	2,028	2,048	2,048	2,048	2,048	2,048
CAP M&I	Freeport-Miami	Gila County	793	1,112	1,690	2,269	2,674	2,877	2,906	2,906	2,906	2,906	2,906
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	779	1,092	1,660	2,229	2,627	2,826	2,854	2,854	2,854	2,854	2,854
CAP M&I	Gilbert	Maricopa County	1,975	2,767	4,209	5,650	6,659	7,163	7,235	7,235	7,235	7,235	7,235
CAP M&I	Glendale	Maricopa County	4,704	6,593	10,026	13,459	15,863	17,064	17,236	17,236	17,236	17,236	17,236
CAP M&I	Goodyear	Maricopa County	2,932	4,109	6,249	8,388	9,886	10,635	10,742	10,742	10,742	10,742	10,742
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	17	24	37	50	59	63	64	64	64	64	64
CAP M&I	Green Valley Community Water Company	Pima County	780	1,093	1,662	2,232	2,630	2,830	2,858	2,858	2,858	2,858	2,858
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	519	727	1,105	1,484	1,749	1,881	1,900	1,900	1,900	1,900	1,900
CAP M&I	Marana	Pima County	638	894	1,359	1,824	2,150	2,313	2,336	2,336	2,336	2,336	2,336
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	182	254	387	519	612	658	665	665	665	665	665
CAP M&I	Mesa	Maricopa County	11,874	16,640	25,305	33,971	40,037	43,070	43,503	43,503	43,503	43,503	43,503

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	3,674	5,148	7,830	10,511	12,388	13,326	13,460	13,460	13,460	13,460	13,460
CAP M&I	Oro Valley	Pima County	2,813	3,942	5,994	8,047	9,484	10,202	10,305	10,305	10,305	10,305	10,305
CAP M&I	Peoria	Maricopa County	7,402	10,374	15,776	21,178	24,960	26,851	27,121	27,121	27,121	27,121	27,121
CAP M&I	Phoenix	Maricopa County	34,419	48,235	73,354	98,473	116,056	124,848	126,104	126,104	126,104	126,104	126,104
CAP M&I	Pine	Gila County	44	62	94	126	148	159	161	161	161	161	161
CAP M&I	Queen Creek	Maricopa County	135	189	288	387	456	490	495	495	495	495	495
CAP M&I	Rio Verde Utilities	Maricopa County	222	311	472	634	747	804	812	812	812	812	812
CAP M&I	San Tan Irrigation District	Maricopa County	64	90	137	184	217	234	236	236	236	236	236
CAP M&I	Scottsdale	Maricopa County	14,414	20,200	30,719	41,239	48,602	52,284	52,810	52,810	52,810	52,810	52,810
CAP M&I	Spanish Trail Water Company	Pima County	829	1,162	1,767	2,372	2,795	3,007	3,037	3,037	3,037	3,037	3,037
CAP M&I	Surprise	Maricopa County	2,797	3,920	5,962	8,003	9,432	10,147	10,249	10,249	10,249	10,249	10,249
CAP M&I	Tempe	Maricopa County	1,178	1,650	2,510	3,370	3,971	4,272	4,315	4,315	4,315	4,315	4,315
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	19	27	41	55	65	70	71	71	71	71	71
CAP M&I	Tucson	Pima County	39,356	55,153	83,875	112,597	132,702	142,755	144,191	144,191	144,191	144,191	144,191
CAP M&I	Vail Water Company	Pima County	507	710	1,080	1,450	1,709	1,839	1,857	1,857	1,857	1,857	1,857
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	797	1,117	1,698	2,279	2,686	2,890	2,919	2,919	2,919	2,919	2,919
4(i)	Arizona State Land Department	Yuma County	184	303	505	718	860	930	1,015	1,015	1,015	1,015	1,015
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	11	18	30	42	50	55	60	60	60	60	60
4(i)	B&F Investment, LLC	La Paz County	7	12	20	28	34	36	40	40	40	40	40
4(i)	Bullhead City	Mohave County	1,824	3,006	5,010	7,118	8,523	9,226	10,065	10,065	10,065	10,065	10,065
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	257	423	705	1,001	1,199	1,297	1,415	1,415	1,415	1,415	1,415
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	839	1,384	2,306	3,276	3,922	4,246	4,632	4,632	4,632	4,632	4,632
4(i)	Bureau of Land Management	La Paz County	740	1,219	2,032	2,887	3,457	3,742	4,082	4,082	4,082	4,082	4,082
4(i)	Crystal Beach Water Conservation District	Mohave County	16	26	43	62	74	80	87	87	87	87	87
4(i)	Ehrenburg Improvement District	La Paz County	88	145	242	344	412	446	486	486	486	486	486
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	225	370	617	877	1,050	1,137	1,240	1,240	1,240	1,240	1,240
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	6	10	17	25	30	32	35	35	35	35	35
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	1	1	1	1	1	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	1	1	2	3	4	4	5	5	5	5	5

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Golden Shores Water Conservation District	Mohave County	240	395	659	936	1,121	1,213	1,323	1,323	1,323	1,323	1,323
4(i)	GSC Farm, LLC	La Paz County	8	14	23	33	39	42	46	46	46	46	46
4(i)	Hillcrest Water Company	La Paz County	10	17	28	39	47	51	56	56	56	56	56
4(i)	Lake Havasu City	Mohave County	2,302	3,794	6,322	8,982	10,755	11,641	12,701	12,701	12,701	12,701	12,701
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	257	423	705	1,001	1,199	1,297	1,415	1,415	1,415	1,415	1,415
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	869	1,433	2,388	3,393	4,063	4,397	4,798	4,798	4,798	4,798	4,798
4(i)	La Paz County	La Paz County	42	69	115	164	196	212	232	232	232	232	232
4(i)	Martinez Lake Cabin Sites	Yuma County	3	5	8	11	13	14	15	15	15	15	15
4(i)	McAlister Family Trust	Mohave County	5	8	13	19	22	24	26	26	26	26	26
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	150	247	412	585	700	758	827	827	827	827	827
4(i)	Mohave Water Conservation District	Mohave County	216	356	593	842	1,009	1,092	1,191	1,191	1,191	1,191	1,191
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	360	593	988	1,404	1,681	1,820	1,985	1,985	1,985	1,985	1,985
4(i)	Parker, Town of[1]	La Paz County	124	204	339	482	577	625	682	682	682	682	682
4(i)	Quartzsite, Town of	La Paz County	128	211	352	501	600	649	708	708	708	708	708
4(i)	Queen Creek, Town of	Maricopa County	341	562	937	1,331	1,593	1,725	1,882	1,882	1,882	1,882	1,882
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	1	1	1	1	1	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	6	10	16	23	28	30	33	33	33	33	33
4(i)	Somerton, City of	Yuma County	90	148	247	351	420	455	496	496	496	496	496
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	12	20	33	47	56	61	66	66	66	66	66
4(i)	TV Marble Canyon AZ, LLC	Coconino County	8	14	23	33	39	42	46	46	46	46	46
3	City of Yuma[1]	Yuma County	0	0	0	0	0	0	21,551	48,522	48,522	48,522	48,522
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	0	0	0	0	0	0	0	25	25	25	25
3	Kaman, Inc.	Yuma County	0	0	0	0	0	0	0	2	2	2	2
3	Department of the Navy, MCAS	Yuma County	0	0	0	0	0	0	0	3,000	3,000	3,000	3,000
3	City of Yuma (cemetery)	Yuma County	0	0	0	0	0	0	0	60	60	60	60
3	Yuma Mesa Fruit Growers' Association	Yuma County	0	0	0	0	0	0	0	15	15	15	15
3	Desert Lawn Memorial Park Association	Yuma County	0	0	0	0	0	0	0	138	138	138	138
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	1,021	1,874	2,726	4,278
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	1,615	2,962	4,309	6,762

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	716	1,314	1,912	3,000
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	659	1,209	1,759	2,760
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	1,194	2,190	3,186	5,000
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	24	44	64	100
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	24	44	64	100
3	Department of the Army - Yuma Proving Ground	Yuma County	0	0	0	0	0	0	0	270	494	719	1,129
3	Yuma Union High School District	Yuma County	0	0	0	0	0	0	0	148	148	148	148
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	0	0	0	0	0	0	0	248	248	248	248
2	Cibola National Wildlife Refuge	La Paz County	0	0	0	0	0	0	502	4,870	7,991	11,111	16,793
2	Lake Mead National Recreation Area	Mohave County	0	0	0	0	0	0	10	99	163	227	343
2	Bureau of Reclamation - Davis Dam	Mohave County	0	0	0	0	0	0	0	2	3	5	7
2	Imperial National Wildlife Refuge	La Paz County	0	0	0	0	0	0	688	6,671	10,944	15,217	23,000
2	Havasu Lake National Wildlife Refuge	Mohave County	0	0	0	0	0	0	1,119	10,847	17,795	24,744	37,399
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 20, Parker, City of	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 21, Yuma, City of	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**275,655**	**349,796**	**483,846**	**618,431**	**712,280**	**759,204**	**793,575**	**849,875**	**868,890**	**887,905**	**922,535**
California			-	-	-	-	-	-	-	-		-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	0	186,000	325,500	325,500	325,500	325,500	362,848	388,002	388,002	388,002	388,002
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	1

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 30, Stephenson	San Bernardino	0	0	0	0	0	0	0	0	0	0	154
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 38, Andrade	San Bernardino	0	0	0	0	0	0	0	0	0	0	42
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 39, Reynolds	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies									
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 43, City of Needles	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**186,000**	**325,500**	**325,500**	**325,500**	**325,500**	**362,848**	**388,002**	**388,002**	**388,002**	**388,210**
Nevada			-	-	-	-	-	-	-	-		-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	21,000	27,000	43,099	64,932	79,486	86,764	92,717	92,717	92,717	92,717	92,717
8	Big Bend Water District	Clark	0	0	0	0	0	0	259	1,790	2,884	3,978	4,900
8	Robert B. Griffith Project	Clark	0	0	0	0	0	0	8,343	57,754	93,047	128,340	158,080
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	0	0	0	0	0	0	0	0	0	5
7	Bureau of Reclamation (includes Sportsman Park)	Clark	0	0	0	0	0	0	0	0	0	0	147
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	0	0	0	0	0	0	0	0	0	0	25
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	0	0	0	0	0	0	0	0	0	0	2,080
6	Las Vegas Valley Water District	Clark	0	0	0	0	0	0	0	0	0	0	8,012
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	0	0	0	0	0	0	0	0	0	0	483
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	4,268
4	City of Henderson	Clark	0	0	0	0	0	0	0	0	0	0	8,257
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	7,774
3	Boulder City	Clark	0	0	0	0	0	0	0	0	0	0	3,056
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	0	0	0	0	0	0	0	0	0	0	1,500
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	0	0	0	0	0	0	0	0	0	0	300
-	-	**Subtotal**	**21,000**	**27,000**	**43,099**	**64,932**	**79,486**	**86,764**	**101,319**	**152,260**	**188,647**	**225,034**	**291,602**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Continuing Current Strategies										
-			613,000	1,013,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	-	**Total**	**296,655**	**562,796**	**852,445**	**1,008,863**	**1,117,266**	**1,171,468**	**1,257,741**	**1,390,137**	**1,445,539**	**1,500,941**	**1,602,347**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	8	14	23	33	39	42	46	46	46	46	46.3223
-	Gila County	-	837	1,173	1,784	2,395	2,823	3,036	3,067	3,067	3,067	3,067	3,067
-	La Paz County	-	1,159	1,911	3,185	4,525	5,418	5,865	7,589	17,939	25,333	32,726	46,191
-	Maricopa County	-	192,180	235,143	313,229	391,335	445,997	473,327	477,370	482,622	487,005	491,388	499,370
-	Mohave County	-	7,569	12,476	20,790	29,537	35,368	38,283	42,896	52,716	59,729	66,743	79,516
-	Pima County	-	62,942	85,270	125,865	166,460	194,877	209,085	211,115	211,115	211,115	211,115	211,115
-	Pinal County	-	10,668	13,331	18,173	23,015	26,404	28,099	28,341	28,341	28,341	28,341	28,341
-	Yuma County	-	290	478	796	1,132	1,355	1,467	23,151	54,029	54,253	54,478	54,888
-	**Subtotal Arizona Domestic**	-	**275,655**	**349,796**	**483,846**	**618,431**	**712,280**	**759,204**	**793,575**	**849,875**	**868,890**	**887,905**	**922,535**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	0	186,000	325,500	325,500	325,500	325,500	362,848	388,002	388,002	388,002	388,002
-	Imperial County	-	0	0	0	0	0	0	0	0	0	0	11
-	Riverside County	-	0	0	0	0	0	0	0	0	0	0	1
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	196
-	**Subtotal California Domestic**	-	**0**	**186,000**	**325,500**	**325,500**	**325,500**	**325,500**	**362,848**	**388,002**	**388,002**	**388,002**	**388,210**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	21,000	27,000	43,099	64,932	79,486	86,764	101,319	152,260	188,647	225,034	291,602
-	**Subtotal Nevada Domestic**	-	**21,000**	**27,000**	**43,099**	**64,932**	**79,486**	**86,764**	**101,319**	**152,260**	**188,647**	**225,034**	**291,602**

Disclaimer: These modeling results for the Continued Current Strategies Comparative Baseline should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]This user also holds a PPR entitlement.

C.6 Lower Basin Priority Shortage Allocation Model

The Lower Basin Priority Shortage Allocation Model represents the shortage distribution specified in the Lower Division States proposal submitted on March 6, 2024. It simulates shortages and distributes available water first among the Lower Division States based on the proposed distribution, and then among the entitlement holders within each state based on priority. The Excel workbook contains formulas to extend the proposed distribution to deeper shortage levels (based on priority) as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.6.1 Present Perfected Rights Assumptions for the Lower Basin Priority Shortage Allocation Model

(See **Section C.3.1** for a discussion on the PPR assumptions in the Priority Shortage Allocation Model.) That discussion is largely applicable to PPR assumptions in the Lower Basin Priority Shortage Allocation Model, but would only be relevant at volumes of shortage that are deeper than proposed by the Lower Division States.

C.6.2 Distribution Among States for the Lower Basin Priority Shortage Allocation Model

The Lower Basin Priority Shortage Allocation Model distributes shortages up to 1.5 maf among states based on state reductions specified in the Lower Division States proposal submitted on March 6, 2024. This includes an Initial Reduction Zone and a Static Reduction Zone, with a Basin-wide Reduction Zone modeled for shortages exceeding 1.5 maf.

C.6.2.1 Shortage Reduction Zone Assumptions

The Initial Reduction zone distributes shortages to the States based on the ratios in the Lower Division States proposal. In the First Initial Reduction Zone of the Lower Basin Priority Shortage Allocation Model, up to 300 kaf of shortages were distributed proportionally between Arizona (80 percent), Nevada (3.33 percent), and Mexico (16.67 percent). In the Second Initial Reduction Zone of the Lower Basin Priority Shortage Allocation Model, total shortages between 300 kaf and 1.5 maf were distributed proportionally between Arizona (43.33 percent), California (36.67 percent), Nevada (3.33 percent), and Mexico (16.67 percent).

The Initial Reduction Zone ramps up to 1.5 maf of shortages, which is distributed in a Static Reduction Zone. In the Static Reduction Zone of 1.5 maf of total shortage, 760 kaf of shortage is distributed to Arizona, 440 kaf of shortage is distributed to California, 50 kaf of shortage is distributed to Nevada, and 250 kaf is distributed to Mexico.

Shortages above 1.5 maf are distributed in the Lower Basin in a Basin-wide[25] Reduction Zone. This zone was split into an Initial Basin-wide Reduction Zone and a Secondary Basin-wide Reduction Zone. In the Initial Basin-wide Reduction Zone, additional shortages beyond the Static Zone are imposed only upon Arizona and Nevada and continue until the deliveries to the post-1968 water entitlement holders in Arizona (including the CAP) are reduced to zero. After deliveries to the fourth priority entitlements within Arizona are expected to be reduced to zero, any additional shortages are applied to Arizona, California, and Nevada in the Secondary Basin-wide Reduction Zone. As with the Priority and Continuing Current Strategies Shortage Allocation Models, the Lower Basin Priority Shortage Allocation Model distributes shortages in excess of 1.5 maf among the Lower Division States in a way that ensures PPRs can be satisfied (or reduced) in the prescribed order as a Basin-wide senior priority group. Instead of setting the entire volume of each state's apportionment as coequal to the others in the Basin-wide reduction zone, only state apportionments in excess of PPRs are treated as coequal (but maintaining the assumption that Arizona bears California's share of shortage until the Arizona fourth priority is exhausted). In developing the Basin-wide Reduction Zone, percentages for the sharing of shortage among the Lower Division States, the consumptive use (or equivalent) of PPR entitlements are removed from the apportionment volumes in each ratio, as detailed below.

The Initial Basin-wide Reduction Zone shortage sharing percentages for the Lower Basin Priority Shortage Allocation Model are computed as follows[26]:

- Nevada bears a reduction of about 8.5 percent of the total Lower Division States shortage volume in the Initial Basin-wide Reduction Zone, computed as a ratio of Nevada's apportionment less PPR consumptive use (or equivalent) entitlements within Nevada less the amount of shortage applied to Nevada under the Static Reduction Zone, over the sum of the apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements less the total amount shorted to the Lower Division States under the Static Reduction Zone
    - (300 kaf – NV PPRs – NV Static Reduction) / (7.5 maf – total PPRs – Lower Division States Static Reduction) = 8.49 percent, or
        - (300 kaf – 8,698 af – 50 kaf) / (7.5 maf – 3,407,835 af – 1.25 maf) = 8.49 percent
- Arizona bears the remainder of the total Lower Division States shortage volume (91.51 percent)

[25] The terminology used for this model is based on the March 6, 2024 proposal, but that proposal did not specify a distribution of the Lower Basin shortage in this zone. Additionally, Reclamation makes no assumption about Upper Basin reductions, and none are included, in the Shortage Allocation Models or Alternative Distribution Models.
[26] Note that these ratios distribute shortage volumes, and the available water is calculated as a remainder.

The Secondary Basin-wide Reduction Zone shortage sharing percentages are computed as follows, with the PPR volumes the same as in the Stage 2 ratios.

- Nevada bears about 8.5 percent of the Secondary Basin-wide Reduction Zone shortage volume in addition to its Static and Initial Basin-wide Reduction Zone shortage, computed as a ratio of Nevada's apportionment less PPR consumptive use (or equivalent) entitlements within Nevada less the amount of shortage applied to Nevada under the Static and Initial Basin-wide Reduction Zone, over the sum of the apportionments of the Lower Division States less all PPR consumptive use (or equivalent) entitlements less the total amount shorted to the Lower Division States under the Static and Initial Basin-wide Reduction Zones
    - (300 kaf – NV PPRs – NV Static Reduction - NV Initial Basin-wide Reduction) / (7.5 maf – total PPRs – Lower Division States Static and Initial Basin-wide Reductions)
        - (300 kaf – 8,698 af – 50 kaf – 59.76 kaf) / (7.5 maf – 3,407,835 af – 1.95 maf) = 8.49 percent
- Arizona bears about 37.3 percent of the Secondary Basin-wide Reduction Zone shortage in addition to its Static and Initial Basin-wide Reduction Zone shortage, computed as a ratio of Arizona's apportionment less PPRs less the amount of shortage applied to Arizona under the Static and Initial Basin-wide Reduction Zone, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to the Lower Division States under the Static and Initial Basin-wide Reduction Zones
    - (2.8 maf – AZ PPRs – AZ Static Reduction - AZ Initial Basin-wide Reduction) / (7.5 maf – total PPRs – Lower Division States Static and Initial Basin-wide Reductions)
        - (2.8 maf - 597,811 af - 760 kaf - 644,130 af) / (7.5 maf - 3,407,835 af - 1,953,891 af) = 37.32 percent
- California bears about 54.2 percent of the Secondary Basin-wide Reduction Zone shortage, computed as a ratio of California's apportionment less PPRs less the amount of shortage applied to California under the Static Reduction Zone, over the sum of the apportionments of the Lower Division States less PPRs less the total amount shorted to the Lower Division States under the Static and Initial Basin-wide Reduction Zones
    - (4.4 maf – CA PPRs – CA Static Reduction) / (7.5 maf – total PPRs – Lower Division States Static and Initial Basin-wide Reductions)
        - (4.4 maf - 2,801,326 af - 440 kaf) / (7.5 maf - 3,407,835 af - 1,953,891 af) = 54.19 percent

For each level of modeled shortage that exceeds the reductions specified in the Lower Division States proposal, the Lower Basin Priority Shortage Allocation Model calculates a percentage

reduction to the Lower Division States and applies the same percentage reduction to Mexico's 1,500,000 acre-feet per year allotment.

Table C-25 below shows a distribution of shortage among the Lower Division States and corresponding volumes of water available to each Lower Division State under the Lower Basin Priority Shortage Allocation Model. Total shortage volumes include an assumed component for Mexico, as described in the sections that follow, and will not sum across rows.

Table C-25
Summary of Shortage Volumes and Available Water by Lower Division State Under the Lower Basin Priority Shortage Allocation Model (af)

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
0	0	2,800,000	0	4,400,000	0	300,000
(10,000)	(8,000)	2,792,000	0	4,400,000	(333)	299,667
(30,000)	(24,000)	2,776,000	0	4,400,000	(1,000)	299,000
(50,000)	(40,000)	2,760,000	0	4,400,000	(1,667)	298,333
(100,000)	(80,000)	2,720,000	0	4,400,000	(3,333)	296,667
(102,500)	(82,000)	2,718,000	0	4,400,000	(3,417)	296,583
(105,000)	(84,000)	2,716,000	0	4,400,000	(3,500)	296,500
(125,000)	(100,000)	2,700,000	0	4,400,000	(4,167)	295,833
(170,000)	(136,000)	2,664,000	0	4,400,000	(5,667)	294,333
(200,000)	(160,000)	2,640,000	0	4,400,000	(6,667)	293,333
(245,000)	(196,000)	2,604,000	0	4,400,000	(8,167)	291,833
(300,000)	(240,000)	2,560,000	0	4,400,000	(10,000)	290,000
(400,000)	(283,333)	2,516,667	(36,667)	4,363,333	(13,333)	286,667
(500,000)	(326,667)	2,473,333	(73,333)	4,326,667	(16,667)	283,333
(510,000)	(331,000)	2,469,000	(77,000)	4,323,000	(17,000)	283,000
(600,000)	(370,000)	2,430,000	(110,000)	4,290,000	(20,000)	280,000
(700,000)	(413,333)	2,386,667	(146,667)	4,253,333	(23,333)	276,667
(800,000)	(456,667)	2,343,333	(183,333)	4,216,667	(26,667)	273,333
(900,000)	(500,000)	2,300,000	(220,000)	4,180,000	(30,000)	270,000
(1,000,000)	(543,333)	2,256,667	(256,667)	4,143,333	(33,333)	266,667
(1,100,000)	(586,667)	2,213,333	(293,333)	4,106,667	(36,667)	263,333
(1,200,000)	(630,000)	2,170,000	(330,000)	4,070,000	(40,000)	260,000
(1,300,000)	(673,333)	2,126,667	(366,667)	4,033,333	(43,333)	256,667
(1,400,000)	(716,667)	2,083,333	(403,333)	3,996,667	(46,667)	253,333
(1,500,000)	(760,000)	2,040,000	(440,000)	3,960,000	(50,000)	250,000
(1,600,000)	(836,258)	1,963,742	(440,000)	3,960,000	(57,075)	242,925
(1,720,000)	(927,768)	1,872,232	(440,000)	3,960,000	(65,565)	234,435
(1,800,000)	(988,775)	1,811,225	(440,000)	3,960,000	(71,225)	228,775

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(1,840,000)	(1,019,278)	1,780,722	(440,000)	3,960,000	(74,055)	225,945
(2,000,000)	(1,141,291)	1,658,709	(440,000)	3,960,000	(85,375)	214,625
(2,080,000)	(1,202,298)	1,597,702	(440,000)	3,960,000	(91,035)	208,965
(2,100,000)	(1,217,550)	1,582,450	(440,000)	3,960,000	(92,450)	207,550
(2,200,000)	(1,293,808)	1,506,192	(440,000)	3,960,000	(99,525)	200,475
(2,300,000)	(1,370,066)	1,429,934	(440,000)	3,960,000	(106,601)	193,399
(2,320,000)	(1,385,318)	1,414,682	(440,000)	3,960,000	(108,016)	191,984
(2,344,669)	(1,404,130)	1,395,870	(440,000)	3,960,000	(109,761)	190,239
(2,400,000)	(1,421,339)	1,378,661	(464,985)	3,935,015	(113,676)	186,324
(2,450,000)	(1,436,890)	1,363,110	(487,563)	3,912,437	(117,213)	182,787
(2,520,000)	(1,458,662)	1,341,338	(519,173)	3,880,827	(122,166)	177,834
(2,600,000)	(1,483,543)	1,316,457	(555,298)	3,844,702	(127,826)	172,174
(2,700,000)	(1,514,646)	1,285,354	(600,454)	3,799,546	(134,901)	165,099
(2,880,000)	(1,570,629)	1,229,371	(681,735)	3,718,265	(147,636)	152,364
(3,000,000)	(1,607,952)	1,192,048	(735,922)	3,664,078	(156,126)	143,874
(3,120,000)	(1,645,274)	1,154,726	(790,109)	3,609,891	(164,616)	135,384
(3,240,000)	(1,682,597)	1,117,403	(844,297)	3,555,703	(173,106)	126,894
(3,360,000)	(1,719,920)	1,080,080	(898,484)	3,501,516	(181,596)	118,404
(3,480,000)	(1,757,242)	1,042,758	(952,671)	3,447,329	(190,086)	109,914
(3,500,000)	(1,763,463)	1,036,537	(961,703)	3,438,297	(191,501)	108,499
(3,600,000)	(1,794,565)	1,005,435	(1,006,859)	3,393,141	(198,576)	101,424
(3,720,000)	(1,831,887)	968,113	(1,061,046)	3,338,954	(207,067)	92,933
(3,840,000)	(1,869,210)	930,790	(1,115,233)	3,284,767	(215,557)	84,443
(4,000,000)	(1,918,973)	881,027	(1,187,483)	3,212,517	(226,877)	73,123
(4,080,000)	(1,943,855)	856,145	(1,223,608)	3,176,392	(232,537)	67,463
(4,200,000)	(1,981,178)	818,822	(1,277,795)	3,122,205	(241,027)	58,973
(4,320,000)	(2,018,500)	781,500	(1,331,983)	3,068,017	(249,517)	50,483
(4,440,000)	(2,055,823)	744,177	(1,386,170)	3,013,830	(258,007)	41,993
(4,530,000)	(2,083,815)	716,185	(1,426,811)	2,973,189	(264,375)	35,625
(4,560,000)	(2,093,145)	706,855	(1,440,358)	2,959,642	(266,497)	33,503
(4,610,000)	(2,108,696)	691,304	(1,462,936)	2,937,064	(270,035)	29,965
(4,680,000)	(2,130,468)	669,532	(1,494,545)	2,905,455	(274,987)	25,013
(4,755,000)	(2,153,794)	646,206	(1,528,412)	2,871,588	(280,294)	19,706
(4,800,000)	(2,167,790)	632,210	(1,548,732)	2,851,268	(283,477)	16,523
(4,900,000)	(2,198,893)	601,107	(1,593,888)	2,806,112	(290,552)	9,448
(4,910,598)	(2,202,189)	597,811	(1,598,674)	2,801,326	(291,302)	8,698
(5,000,000)	(2,256,342)	543,658	(1,618,723)	2,781,277	(291,602)	8,398
(6,000,000)	(2,383,742)	416,258	(2,324,655)	2,075,345	(291,602)	8,398
(7,000,000)	(2,383,742)	416,258	(3,157,989)	1,242,011	(291,602)	8,398

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(7,500,000)	(2,383,742)	416,258	(3,574,655)	825,345	(291,602)	8,398
(9,000,000)	(2,800,000)	0	(4,400,000)	0	(300,000)	0

C.6.3 Distribution Within States for the Lower Basin Priority Shortage Allocation Model

To estimate the impacts of given levels of shortage, assumptions were made with regard to how shortages might be shared. These assumptions are made to facilitate analysis of the potential impacts and they are not intended to represent current or future policy with respect to shortage allocation. The Lower Basin Priority Shortage Allocation Model is not designed to replicate some of the annual processes that must be undertaken in determining the quantity of water that can be approved for diversion by specific users.

Other than the state-level distribution of shortage as described above, modeling assumptions match the Priority Shortage Allocation Model.

C.6.4 Lower Basin Priority Shortage Allocation Model Results

The tables in this section present the results of the Lower Basin Priority Shortage Allocation Model over a range of total shortages to the Lower Basin including Mexico.

Table C-26, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-27, the Tribal Summary, presents the shortage impacts on tribes.

Table C-28, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-29, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-26
Lower Basin Priority Shortage Allocation Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
Arizona	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion	364,455	520,455	715,455	921,352	1,058,617	1,127,250	1,264,514	1,295,172	1,295,172	1,295,172	1,295,172
-	NIA Priority[2]	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415	273,415
-	M&I Priority[2]	86,076	186,794	310,863	447,949	530,661	575,198	638,823	638,823	638,823	638,823	638,823
-	Indian Priority[2]	29,366	84,648	155,579	233,953	281,241	306,704	343,079	343,079	343,079	343,079	343,079
-	4th Priority i (Mainstream)	5,545	22,878	44,545	67,423	82,674	90,300	105,552	108,958	108,958	108,958	108,958
-	2nd & 3rd Priorities	0	0	0	0	0	0	0	203,822	359,333	514,843	798,059
-	1st Priority (Present Perfected Rights)	0	0	0	0	0	0	0	0	0	0	54,153
-	**Subtotal**	**370,000**	**543,333**	**760,000**	**988,775**	**1,141,291**	**1,217,550**	**1,370,066**	**1,607,952**	**1,763,463**	**1,918,973**	**2,256,342**
California	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	110,000	256,667	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002
-	3rd Priority (IID, CVWD, PVID)	0	0	51,998	51,998	51,998	51,998	51,998	347,920	573,701	799,481	835,000
-	2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0	0	0	0	0	0	7,294
-	1st Priority (PVID)	0	0	0	0	0	0	0	0	0	0	368,378
-	Present Perfected Rights (PPRs)	0	0	0	0	0	0	0	0	0	0	20,049
-	**Subtotal**	**110,000**	**256,667**	**440,000**	**440,000**	**440,000**	**440,000**	**440,000**	**735,922**	**961,703**	**1,187,483**	**1,618,723**
Nevada	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	20,000	33,333	50,000	71,225	85,375	92,450	92,717	92,717	92,717	92,717	92,717
-	8th Priority (SNWA & Big Bend)	0	0	0	0	0	0	13,884	63,409	98,785	134,160	162,980
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	0	0	0	0	0	0	0	0	0	0	2,257
-	6th Priority (Las Vegas Valley Water District)	0	0	0	0	0	0	0	0	0	0	8,012
-	5th Priority (PABCO)	0	0	0	0	0	0	0	0	0	0	483
-	4th Priority (Henderson & Basic)	0	0	0	0	0	0	0	0	0	0	20,299

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority										
-	**-**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	3rd Priority (Boulder City)	0	0	0	0	0	0	0	0	0	0	3,056
-	2nd Priority (Lake Mead National Rec Area)	0	0	0	0	0	0	0	0	0	0	1,500
-	1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	0	0	0	0	0	0	0	0	0	0	300
-	**Subtotal**	**20,000**	**33,333**	**50,000**	**71,225**	**85,375**	**92,450**	**106,601**	**156,126**	**191,501**	**226,877**	**291,602**
-	**Lower Division States Subtotal**	**500,000**	**833,333**	**1,250,000**	**1,500,000**	**1,666,667**	**1,750,000**	**1,916,667**	**2,500,000**	**2,916,667**	**3,333,333**	**4,166,667**
Mexico	**Mexico Subtotal**	**100,000**	**166,667**	**250,000**	**300,000**	**333,333**	**350,000**	**383,333**	**500,000**	**583,333**	**666,667**	**833,333**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

Disclaimer: These modeling results for the Lower Basin Priority should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Volumes of total shortage include a portion modeled as attributed to Mexico, but that portion is not itemized in summary sheets.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here
[2]These estimated shortages to priorities within the CAP reflect the effect of CAP system loss, and do not total to CAP shortage at the point of diversion.

Table C-27
Lower Basin Priority Shortage Allocation Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782	23,782
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200	28,200
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600	120,600
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	29,366	60,089	96,075	135,837	159,828	172,746	191,200	191,200	191,200	191,200	191,200
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	0	4,297	13,492	23,653	29,783	33,084	37,800	37,800	37,800	37,800	37,800
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	0	138	435	762	960	1,066	1,218	1,218	1,218	1,218	1,218
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	0	11,794	24,559	38,662	47,172	51,754	58,300	58,300	58,300	58,300	58,300
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	0	2,073	6,508	11,409	14,366	15,958	18,233	18,233	18,233	18,233	18,233
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	0	57	178	313	394	438	500	500	500	500	500
CAP Indian Priority	San Carlos Apache Tribe	Gila County	0	1,683	4,707	8,048	10,064	11,149	12,700	12,700	12,700	12,700	12,700
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	0	2,691	5,603	8,820	10,761	11,807	13,300	13,300	13,300	13,300	13,300
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	0	1,618	3,370	5,305	6,473	7,102	8,000	8,000	8,000	8,000	8,000
CAP Indian Priority	Tonto Apache Tribe	Gila County	0	15	46	80	101	112	128	128	128	128	128
CAP Indian Priority	Yavapai Apache Nation	Gila County	0	136	428	751	946	1,050	1,200	1,200	1,200	1,200	1,200
CAP M&I Priority	San Carlos Apache Tribe	Gila County	2,445	5,306	8,830	12,723	15,073	16,338	18,145	18,145	18,145	18,145	18,145
4(i)	Hopi Tribe[1]	La Paz County	144	594	1,157	1,752	2,148	2,346	2,742	2,831	2,831	2,831	2,831
4(i)	Cocopah Indian Reservation	Yuma County	68	282	548	830	1,017	1,111	1,299	1,341	1,341	1,341	1,341
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	118	486	947	1,433	1,757	1,920	2,244	2,316	2,316	2,316	2,316
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	345	1,421	2,768	4,189	5,137	5,610	6,558	6,770	6,770	6,770	6,770

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	10,082	20,528	30,975	50,000
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**209,068**	**269,262**	**346,233**	**431,150**	**482,561**	**510,173**	**550,149**	**560,645**	**571,092**	**581,538**	**600,563**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**209,068**	**269,262**	**346,233**	**431,150**	**482,561**	**510,173**	**550,149**	**560,645**	**571,092**	**581,538**	**600,563**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
_			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
			-	-	-	-	-	-	-	-	-	-	-
_	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
_	Coconino County	-	2,039	2,162	2,316	2,478	2,586	2,640	2,748	2,772	2,772	2,772	2,772
_	Gila County	-	10,372	15,113	22,083	29,784	34,430	36,932	40,506	40,506	40,506	40,506	40,506
_	La Paz County	-	144	594	1,157	1,752	2,148	2,346	2,742	2,831	2,831	2,831	2,831
_	Maricopa County	-	44,990	58,970	77,113	97,160	109,256	115,769	125,073	125,073	125,073	125,073	125,073
_	Mohave County	-	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
_	Pima County	-	28,200	32,554	41,871	52,166	58,377	61,722	66,500	66,500	66,500	66,500	66,500
_	Pinal County	-	104,976	139,895	179,601	223,474	249,944	264,198	284,560	294,642	305,088	315,535	334,560
_	Yuma County	-	413	1,703	3,316	5,019	6,154	6,722	7,857	8,110	8,110	8,110	8,110
_	Apache County	-	7,967	8,136	8,388	8,659	8,833	8,923	9,081	9,105	9,105	9,105	9,105
_	Navajo County	-	7,967	8,136	8,388	8,659	8,833	8,923	9,081	9,105	9,105	9,105	9,105
_	**Subtotal Arizona Tribal**	-	**209,068**	**269,262**	**346,233**	**431,150**	**482,561**	**510,173**	**550,149**	**560,645**	**571,092**	**581,538**	**600,563**
_	**California**	-	-	-	-	-	-	-	-	-	-	-	-
_	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
_	Riverside	-	-	-	-	-	-	-	-	-	-	-	-
_	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
_	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
_	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
_	Clark	-	0	0	0	0	0	0	0	0	0	0	0
_	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Disclaimer: These modeling results for the Lower Basin Priority should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Table C-28
Lower Basin Priority Shortage Allocation Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	96	394	768	1,162	1,425	1,556	1,819	1,878	1,878	1,878	1,878
4(i)	Arizona State Land Department	Yuma County	223	918	1,787	2,705	3,317	3,623	4,235	4,372	4,372	4,372	4,372
4(i)	Beattie Farms, Southwest	Yuma County	37	154	300	455	557	609	712	735	735	735	735
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	14	58	114	172	211	230	269	278	278	278	278
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	4	18	34	52	63	69	81	83	83	83	83
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	71	292	568	860	1,054	1,152	1,346	1,390	1,390	1,390	1,390
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	7	30	58	88	108	118	138	143	143	143	143
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	251	1,034	2,014	3,048	3,737	4,082	4,771	4,925	4,925	4,925	4,925
4(i)	Curtis, Armon	Yuma County	10	42	81	123	151	165	192	199	199	199	199
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	48	199	388	588	721	787	920	950	950	950	950
4(i)	Matador Farms, LLC	La Paz County	152	625	1,217	1,843	2,260	2,468	2,885	2,978	2,978	2,978	2,978
4(i)	JRJ Partners, L.L.C.	Yuma County	36	150	292	442	542	592	692	715	715	715	715
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	1,181	4,872	9,485	14,357	17,604	19,228	22,476	23,201	23,201	23,201	23,201
4(i)	North Baja Pipeline, LLC[2]	La Paz County	16	67	130	197	241	263	308	318	318	318	318
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	31	128	250	378	464	507	592	611	611	611	611
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	16	67	130	197	241	263	308	318	318	318	318
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	16	68	131	199	244	267	312	322	322	322	322
4(i)	Red River Land Company, LLC	La Paz County	10	42	81	123	151	165	192	199	199	199	199
4(i)	Phillips, Milton and Jean	Yuma County	2	8	16	25	30	33	38	40	40	40	40
4(i)	Western Water, LLC	La Paz County	18	75	145	220	269	294	344	355	355	355	355
3	Sturges, Harold	Yuma County	0	0	0	0	0	0	0	335	335	335	335
3	Sturges, Irma	Yuma County	0	0	0	0	0	0	0	385	385	385	385
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	26,459	56,570	86,681	141,519

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	12,578	26,893	41,208	67,278
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	0	0	0	0	0	0	0	1,258	2,691	4,123	6,731
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	0	0	0	0	0	0	0	56,054	114,137	172,220	278,000
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	0	0	0	0	0	0	0	722	1,471	2,219	3,582
3	Yuma County Water Users' Association (14,701af M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	0	0	0	0	0	0	0	15,872	32,472	49,072	79,304
3	University of Arizona	Yuma County	0	0	0	0	0	0	0	1,088	1,088	1,088	1,088
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	0	0	0	0	0	0	0	120	120	120	120
3	Unit B Irrigation & Drainage District[3]	Yuma County	0	0	0	0	0	0	0	2,242	6,074	9,906	16,886
1	PPR No. 15, Molina	Yuma County	0	0	0	0	0	0	0	0	0	0	318
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	0	0	0	0	0	0	0	0	0	0	445
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	0	0	0	0	0	0	0	0	0	0	4,352
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	0	0	0	0	0	0	0	0	0	0	6,125
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	0	0	0	0	0	0	0	0	0	0	42,914
1	PPR No. 7, Powers	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 10, Hulet (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 12, Miller (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 18, Swan (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**2,240**	**9,240**	**17,991**	**27,231**	**33,391**	**36,471**	**42,631**	**161,121**	**286,243**	**411,364**	**693,389**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	0	0	311	311	311	311	311	2,083	3,435	4,787	5,000
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	0	0	51,687	51,687	51,687	51,687	51,687	330,000	330,000	330,000	330,000
3	Imperial Irrigation District (IID) (3a)	Imperial County	0	0	0	0	0	0	0	15,837	240,265	464,694	500,000
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	0	0	0	0	0	0	0	0	0	0	7,294
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	368,378
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	0	0	0	0	0	0	0	0	0	0	115
PPR	PPR No. 41, Chagnon	San Bernardino	0	0	0	0	0	0	0	0	0	0	77
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	0	0	0	0	0	0	0	0	0	0	61
PPR	PPR No. 34, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	69
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	0	0	0	0	0	0	0	0	0	0	19,518
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 42, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 37, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 33, Morgan	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 35, Simons	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**51,998**	**51,998**	**51,998**	**51,998**	**51,998**	**347,920**	**573,701**	**799,481**	**1,230,512**
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**2,240**	**9,240**	**69,989**	**79,229**	**85,389**	**88,469**	**94,629**	**509,041**	**859,943**	**1,210,846**	**1,923,901**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
			-	-	-	-	-	-	-	-	-	-	-
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	568	2,343	4,561	6,904	8,465	9,246	10,808	11,156	11,156	11,156	11,156
-	Mohave County	-	1,181	4,872	9,485	14,357	17,604	19,228	22,476	23,201	23,201	23,201	23,201
-	Yuma County	-	491	2,026	3,945	5,971	7,322	7,997	9,348	126,763	251,885	377,007	659,032
-	**Subtotal Arizona Irrigation**	-	**2,240**	**9,240**	**17,991**	**27,231**	**33,391**	**36,471**	**42,631**	**161,121**	**286,243**	**411,364**	**693,389**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	0	0	51,998	51,998	51,998	51,998	51,998	332,083	333,435	334,787	519,189
-	Imperial County	-	0	0	0	0	0	0	0	15,837	240,265	464,694	711,185
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	138
-	**Subtotal California Irrigation**	-	**0**	**0**	**51,998**	**51,998**	**51,998**	**51,998**	**51,998**	**347,920**	**573,701**	**799,481**	**1,230,512**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

Disclaimer: These modeling results for the Lower Basin Priority should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Table C-29
Lower Basin Priority Shortage Allocation Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185
CAP NIA-B	Carefree Water Company	Maricopa County	112	112	112	112	112	112	112	112	112	112	112
CAP NIA-B	Cave Creek	Maricopa County	386	386	386	386	386	386	386	386	386	386	386
CAP NIA-B	El Mirage	Maricopa County	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217
CAP NIA-B	Freeport	Pima County	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678
CAP NIA-B	Gilbert	Maricopa County	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832
CAP NIA-B	Marana	Pima County	515	515	515	515	515	515	515	515	515	515	515
CAP NIA-B	Queen Creek	Maricopa County	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162
CAP NIA-B	Resolution Copper	Maricopa County	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238
CAP NIA-B	Rosemont Copper	Pima County	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124
CAP NIA-B	SRP	Maricopa County	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	817	817	817	817	817	817	817	817	817	817	817
CAP NIA-A	Phoenix	Maricopa County	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280
CAP NIA-A	Chandler	Maricopa County	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924
CAP NIA-A	Gilbert	Maricopa County	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537
CAP NIA-A	Glendale	Maricopa County	682	682	682	682	682	682	682	682	682	682	682
CAP NIA-A	Mesa	Maricopa County	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551
CAP NIA-A	Scottsdale	Maricopa County	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Tempe	Maricopa County	23	23	23	23	23	23	23	23	23	23	23
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	0	57	178	313	394	438	500	500	500	500	500
CAP M&I	ASARCO	Pima County	2,830	6,140	10,219	14,725	17,444	18,908	21,000	21,000	21,000	21,000	21,000
CAP M&I	Avondale	Maricopa County	730	1,584	2,636	3,798	4,499	4,877	5,416	5,416	5,416	5,416	5,416
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	3,796	8,239	13,711	19,757	23,405	25,370	28,176	28,176	28,176	28,176	28,176
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	1,197	2,598	4,323	6,230	7,380	7,999	8,884	8,884	8,884	8,884	8,884
CAP M&I	Arizona Water Company, Coolidge	Pinal County	269	585	973	1,402	1,661	1,801	2,000	2,000	2,000	2,000	2,000
CAP M&I	Arizona Water Company, Superstition	Pinal County	847	1,838	3,058	4,407	5,221	5,659	6,285	6,285	6,285	6,285	6,285
CAP M&I	Arizona Water Company, White Tank	Maricopa County	130	283	471	679	804	872	968	968	968	968	968
CAP M&I	Buckeye	Maricopa County	9	20	33	48	56	61	68	68	68	68	68
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	866	1,879	3,127	4,506	5,338	5,786	6,426	6,426	6,426	6,426	6,426
CAP M&I	Carefree Water Company	Maricopa County	226	491	817	1,177	1,394	1,511	1,678	1,678	1,678	1,678	1,678
CAP M&I	Cave Creek	Maricopa County	300	651	1,084	1,562	1,851	2,006	2,228	2,228	2,228	2,228	2,228
CAP M&I	Chandler	Maricopa County	1,166	2,530	4,211	6,068	7,189	7,792	8,654	8,654	8,654	8,654	8,654
CAP M&I	Chaparral City Water Company	Maricopa County	1,200	2,605	4,335	6,247	7,401	8,022	8,909	8,909	8,909	8,909	8,909
CAP M&I	Circle City	Maricopa County	530	1,150	1,913	2,757	3,266	3,540	3,932	3,932	3,932	3,932	3,932
CAP M&I	El Mirage	Maricopa County	68	149	247	356	422	457	508	508	508	508	508
CAP M&I	Eloy	Pinal County	293	635	1,056	1,522	1,803	1,955	2,171	2,171	2,171	2,171	2,171
CAP M&I	EPCOR, Agua Fria	Maricopa County	1,495	3,244	5,398	7,779	9,215	9,988	11,093	11,093	11,093	11,093	11,093
CAP M&I	EPCOR, Paradise Valley	Maricopa County	435	945	1,572	2,266	2,684	2,909	3,231	3,231	3,231	3,231	3,231
CAP M&I	EPCOR, Sun City	Maricopa County	564	1,225	2,038	2,937	3,480	3,772	4,189	4,189	4,189	4,189	4,189
CAP M&I	EPCOR, Sun City West	Maricopa County	320	694	1,154	1,663	1,970	2,136	2,372	2,372	2,372	2,372	2,372
CAP M&I	Florence	Pinal County	276	599	997	1,436	1,701	1,844	2,048	2,048	2,048	2,048	2,048
CAP M&I	Freeport-Miami	Gila County	392	850	1,414	2,038	2,414	2,617	2,906	2,906	2,906	2,906	2,906

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	385	835	1,389	2,001	2,371	2,570	2,854	2,854	2,854	2,854	2,854
CAP M&I	Gilbert	Maricopa County	975	2,116	3,521	5,073	6,010	6,514	7,235	7,235	7,235	7,235	7,235
CAP M&I	Glendale	Maricopa County	2,322	5,040	8,387	12,086	14,318	15,519	17,236	17,236	17,236	17,236	17,236
CAP M&I	Goodyear	Maricopa County	1,447	3,141	5,227	7,532	8,923	9,672	10,742	10,742	10,742	10,742	10,742
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	9	19	31	45	53	58	64	64	64	64	64
CAP M&I	Green Valley Community Water Company	Pima County	385	836	1,391	2,004	2,374	2,573	2,858	2,858	2,858	2,858	2,858
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	256	556	925	1,332	1,578	1,711	1,900	1,900	1,900	1,900	1,900
CAP M&I	Marana	Pima County	315	683	1,137	1,638	1,940	2,103	2,336	2,336	2,336	2,336	2,336
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	90	194	324	466	552	599	665	665	665	665	665
CAP M&I	Mesa	Maricopa County	5,862	12,720	21,169	30,505	36,137	39,170	43,503	43,503	43,503	43,503	43,503
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	1,814	3,936	6,550	9,438	11,181	12,119	13,460	13,460	13,460	13,460	13,460
CAP M&I	Oro Valley	Pima County	1,389	3,013	5,015	7,226	8,560	9,279	10,305	10,305	10,305	10,305	10,305
CAP M&I	Peoria	Maricopa County	3,654	7,930	13,198	19,017	22,529	24,420	27,121	27,121	27,121	27,121	27,121
CAP M&I	Phoenix	Maricopa County	16,991	36,873	61,364	88,425	104,753	113,544	126,104	126,104	126,104	126,104	126,104
CAP M&I	Pine	Gila County	22	47	78	113	134	145	161	161	161	161	161
CAP M&I	Queen Creek	Maricopa County	67	145	241	347	411	446	495	495	495	495	495
CAP M&I	Rio Verde Utilities	Maricopa County	109	237	395	569	675	731	812	812	812	812	812
CAP M&I	San Tan Irrigation District	Maricopa County	32	69	115	165	196	212	236	236	236	236	236
CAP M&I	Scottsdale	Maricopa County	7,116	15,442	25,698	37,031	43,868	47,550	52,810	52,810	52,810	52,810	52,810
CAP M&I	Spanish Trail Water Company	Pima County	409	888	1,478	2,130	2,523	2,735	3,037	3,037	3,037	3,037	3,037
CAP M&I	Surprise	Maricopa County	1,381	2,997	4,987	7,187	8,514	9,228	10,249	10,249	10,249	10,249	10,249
CAP M&I	Tempe	Maricopa County	581	1,262	2,100	3,026	3,584	3,885	4,315	4,315	4,315	4,315	4,315
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	10	21	35	50	59	64	71	71	71	71	71
CAP M&I	Tucson	Pima County	19,428	42,162	70,166	101,108	119,777	129,830	144,191	144,191	144,191	144,191	144,191
CAP M&I	Vail Water Company	Pima County	250	543	904	1,302	1,543	1,672	1,857	1,857	1,857	1,857	1,857

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	393	854	1,420	2,047	2,425	2,628	2,919	2,919	2,919	2,919	2,919
4(i)	Arizona State Land Department	Yuma County	52	213	415	628	770	841	983	1,015	1,015	1,015	1,015
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	3	13	24	37	45	49	58	60	60	60	60
4(i)	B&F Investment, LLC	La Paz County	2	8	16	25	30	33	38	40	40	40	40
4(i)	Bullhead City	Mohave County	512	2,113	4,115	6,228	7,637	8,342	9,751	10,065	10,065	10,065	10,065
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	72	297	579	876	1,074	1,173	1,371	1,415	1,415	1,415	1,415
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	236	973	1,894	2,866	3,515	3,839	4,487	4,632	4,632	4,632	4,632
4(i)	Bureau of Land Management	La Paz County	208	857	1,669	2,526	3,098	3,383	3,955	4,082	4,082	4,082	4,082
4(i)	Crystal Beach Water Conservation District	Mohave County	4	18	36	54	66	72	85	87	87	87	87
4(i)	Ehrenburg Improvement District	La Paz County	25	102	199	301	369	403	471	486	486	486	486
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	63	260	507	767	941	1,028	1,201	1,240	1,240	1,240	1,240
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	2	7	14	22	27	29	34	35	35	35	35
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	1	1	1	1	1	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	0	1	2	3	4	4	4	5	5	5	5
4(i)	Golden Shores Water Conservation District	Mohave County	67	278	541	819	1,004	1,097	1,282	1,323	1,323	1,323	1,323
4(i)	GSC Farm, LLC	La Paz County	2	10	19	29	35	38	45	46	46	46	46
4(i)	Hillcrest Water Company	La Paz County	3	12	23	34	42	46	54	56	56	56	56
4(i)	Lake Havasu City	Mohave County	646	2,667	5,192	7,859	9,637	10,526	12,304	12,701	12,701	12,701	12,701
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	72	297	579	876	1,074	1,173	1,371	1,415	1,415	1,415	1,415
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	244	1,007	1,961	2,969	3,640	3,976	4,648	4,798	4,798	4,798	4,798
4(i)	La Paz County	La Paz County	12	49	95	143	176	192	224	232	232	232	232
4(i)	Martinez Lake Cabin Sites	Yuma County	1	3	6	9	12	13	15	15	15	15	15

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	McAlister Family Trust	Mohave County	1	6	11	16	20	22	26	26	26	26	26
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	42	174	338	512	628	686	801	827	827	827	827
4(i)	Mohave Water Conservation District	Mohave County	61	250	487	737	904	987	1,154	1,191	1,191	1,191	1,191
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	101	417	812	1,228	1,506	1,645	1,923	1,985	1,985	1,985	1,985
4(i)	Parker, Town of[1]	La Paz County	35	143	279	422	517	565	660	682	682	682	682
4(i)	Quartzsite, Town of	La Paz County	36	149	289	438	537	587	686	708	708	708	708
4(i)	Queen Creek, Town of	Maricopa County	96	395	769	1,164	1,428	1,559	1,823	1,882	1,882	1,882	1,882
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	1	1	1	1	1	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	2	7	14	20	25	27	32	33	33	33	33
4(i)	Somerton, City of	Yuma County	25	104	203	307	377	411	481	496	496	496	496
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	3	14	27	41	50	55	64	66	66	66	66
4(i)	TV Marble Canyon AZ, LLC	Coconino County	2	10	19	29	35	38	45	46	46	46	46
3	City of Yuma[1]	Yuma County	0	0	0	0	0	0	0	48,522	48,522	48,522	48,522
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	0	0	0	0	0	0	0	25	25	25	25
3	Kaman, Inc.	Yuma County	0	0	0	0	0	0	0	2	2	2	2
3	Department of the Navy, MCAS	Yuma County	0	0	0	0	0	0	0	3,000	3,000	3,000	3,000
3	City of Yuma (cemetery)	Yuma County	0	0	0	0	0	0	0	60	60	60	60
3	Yuma Mesa Fruit Growers' Association	Yuma County	0	0	0	0	0	0	0	15	15	15	15
3	Desert Lawn Memorial Park Association	Yuma County	0	0	0	0	0	0	0	138	138	138	138
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	863	1,756	2,650	4,278
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	1,363	2,776	4,189	6,762
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	605	1,232	1,858	3,000
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	557	1,133	1,710	2,760

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	1,008	2,053	3,097	5,000
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	20	41	62	100
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	0	0	0	0	0	20	41	62	100
3	Department of the Army - Yuma Proving Ground	Yuma County	0	0	0	0	0	0	0	228	464	699	1,129
3	Yuma Union High School District	Yuma County	0	0	0	0	0	0	0	148	148	148	148
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	0	0	0	0	0	0	0	248	248	248	248
2	Cibola National Wildlife Refuge	La Paz County	0	0	0	0	0	0	0	4,289	7,561	10,833	16,793
2	Lake Mead National Recreation Area	Mohave County	0	0	0	0	0	0	0	88	154	221	343
2	Bureau of Reclamation - Davis Dam	Mohave County	0	0	0	0	0	0	0	2	3	5	7
2	Imperial National Wildlife Refuge	La Paz County	0	0	0	0	0	0	0	5,874	10,356	14,838	23,000
2	Havasu Lake National Wildlife Refuge	Mohave County	0	0	0	0	0	0	0	9,552	16,839	24,127	37,399
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 20, Parker, City of	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 21, Yuma, City of	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**183,095**	**289,233**	**420,178**	**564,359**	**652,039**	**698,973**	**768,089**	**846,331**	**866,273**	**886,216**	**922,535**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	110,000	256,667	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	1

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 30, Stephenson	San Bernardino	0	0	0	0	0	0	0	0	0	0	154
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 38, Andrade	San Bernardino	0	0	0	0	0	0	0	0	0	0	42
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 39, Reynolds	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 43, City of Needles	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**110,000**	**256,667**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,210**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	20,000	33,333	50,000	71,225	85,375	92,450	92,717	92,717	92,717	92,717	92,717
8	Big Bend Water District	Clark	0	0	0	0	0	0	417	1,906	2,970	4,034	4,900

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
8	Robert B. Griffith Project	Clark	0	0	0	0	0	0	13,467	61,503	95,815	130,127	158,080
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	0	0	0	0	0	0	0	0	0	5
7	Bureau of Reclamation (includes Sportsman Park)	Clark	0	0	0	0	0	0	0	0	0	0	147
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	0	0	0	0	0	0	0	0	0	0	25
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	0	0	0	0	0	0	0	0	0	0	2,080
6	Las Vegas Valley Water District	Clark	0	0	0	0	0	0	0	0	0	0	8,012
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	0	0	0	0	0	0	0	0	0	0	483
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	4,268
4	City of Henderson	Clark	0	0	0	0	0	0	0	0	0	0	8,257
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	0	7,774
3	Boulder City	Clark	0	0	0	0	0	0	0	0	0	0	3,056
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	0	0	0	0	0	0	0	0	0	0	1,500
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	0	0	0	0	0	0	0	0	0	0	300
-	-	**Subtotal**	**20,000**	**33,333**	**50,000**	**71,225**	**85,375**	**92,450**	**106,601**	**156,126**	**191,501**	**226,877**	**291,602**
-	-	**Total**	**313,095**	**579,233**	**858,180**	**1,023,586**	**1,125,416**	**1,179,425**	**1,262,691**	**1,390,459**	**1,445,777**	**1,501,094**	**1,602,347**
	Summary by County												
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	2	10	19	29	35	38	45	46	46	46	46
-	Gila County	-	413	897	1,492	2,151	2,548	2,762	3,067	3,067	3,067	3,067	3,067
-	La Paz County	-	326	1,343	2,616	3,959	4,855	5,303	6,198	16,561	24,316	32,070	46,191
-	Maricopa County	-	138,060	199,827	275,970	360,084	410,861	438,191	477,311	481,806	486,402	490,998	499,370
-	Mohave County	-	2,126	8,770	17,076	25,845	31,692	34,615	40,462	51,408	58,764	66,120	79,516
-	Pima County	-	34,777	66,908	106,489	150,222	176,609	190,817	211,115	211,115	211,115	211,115	211,115
-	Pinal County	-	7,309	11,141	15,862	21,078	24,225	25,920	28,341	28,341	28,341	28,341	28,341

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Priority									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	Yuma County	-	81	336	654	990	1,214	1,326	1,550	53,987	54,222	54,458	54,888
-	**Subtotal Arizona Domestic**	-	**183,095**	**289,233**	**420,178**	**564,359**	**652,039**	**698,973**	**768,089**	**846,331**	**866,273**	**886,216**	**922,535**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	110,000	256,667	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002	388,002
-	Imperial County	-	0	0	0	0	0	0	0	0	0	0	11
-	Riverside County	-	0	0	0	0	0	0	0	0	0	0	1
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	196
-	**Subtotal California Domestic**	-	**110,000**	**256,667**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,210**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	20,000	33,333	50,000	71,225	85,375	92,450	106,601	156,126	191,501	226,877	291,602
-	**Subtotal Nevada Domestic**	-	**20,000**	**33,333**	**50,000**	**71,225**	**85,375**	**92,450**	**106,601**	**156,126**	**191,501**	**226,877**	**291,602**

Disclaimer: These modeling results for the Lower Basin Priority should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]This user also holds a PPR entitlement.

C.7 Priority Without Tribal Shortage Alternative Distribution Model

The Priority Without Tribal Shortage Alternative Distribution Model simulates a distribution of water which fully fills all tribal entitlements, distributing shortage among non-tribal entitlements in accordance with elements of the existing priority system. This Alternative Distribution Model reflects a modeling commitment to stakeholders to display a possible distribution of water during shortage that does not short tribal entitlements or allocations; it is not an interpretation of law, contracts, or a legal position.

For each level of modeled shortage, the Priority Without Tribal Shortage Alternative Distribution Model calculates a percentage reduction to the Lower Division States and applies the same percentage reduction to Mexico's 1,500,000 acre-feet per year allotment.

The Excel workbook contains formulas extending into deep shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.7.1 Entitlements Which are Not Shorted in the Priority Without Tribal Shortage Alternative Distribution Model

For modeling purposes, the entitlements/allocations in **Table C-30** below have been removed from the priorities in which they are situate pursuant to contracts or other documents, and the sizes of those priority pools are adjusted accordingly. The priority of these entitlements is identified in the Excel workbook and the table below for the purpose of cross-reference, but the fulfillment of these entitlements in the Alternative Distribution Model is no longer dictated by priority; the model does not attempt to emulate shortage deep enough to affect them. Note that CAP allocations are shown for modeling purposes as mainstream consumptive use equivalents, with 5 percent for CAP system loss added to the contract volume. All other entitlements are shown as calculated for the Priority Shortage Allocation Model.

Table C-30
Entitlements and Allocations Not Shorted Under Priority Without Tribal Shortage Alternative Distribution Model

State	Priority	Entitlement Holder, Contractor, or Subcontractor	Consumptive Use or Equivalent Entitlement (af)*
Arizona	CAP NIA-B	White Mountain Apache Tribe	24,971.10
Arizona	CAP NIA-A	Gila River Indian Community	126,630.00
Arizona	CAP NIA-A	Tohono O'odham - Schuk Toak & San Xavier	29,610.00
Arizona	CAP NIA-A	Hualapai Tribe**	4,200.00
Arizona	CAP M&I	San Carlos Apache Tribe	19,052.25

State	Priority	Entitlement Holder, Contractor, or Subcontractor	Consumptive Use or Equivalent Entitlement (af)*
Arizona	CAP Indian	Gila River Indian Community	200,760.00
Arizona	CAP Indian	Tohono O'odham Nation (ST & SX)	39,690.00
Arizona	CAP Indian	White Mountain Apache Tribe	1,278.90
Arizona	CAP Indian	Ak-Chin Indian Community	61,215.00
Arizona	CAP Indian	Fort McDowell Yavapai Nation	19,144.65
Arizona	CAP Indian	Pascua Yaqui Tribe	525.00
Arizona	CAP Indian	San Carlos Apache Tribe	13,335.00
Arizona	CAP Indian	Salt River Pima-Maricopa Indian Community	13,965.00
Arizona	CAP Indian	Tohono O'odham Nation Sif Oidak District	8,400.00
Arizona	CAP Indian	Tonto Apache Tribe	134.40
Arizona	CAP Indian	Yavapai Apache Nation	1,260.00
Arizona	P4(i)	Cocopah Indian Reservation	1,357.42
Arizona	P4(i)	Hopi Tribe	3,037.38
Arizona	P4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	3,500.00
Arizona	P4(i)	Unallocated 4th Priority Mainstream Water	10,230.00
Arizona	P3	Ak-Chin Indian Community	50,000.00
Arizona	PPR	Cocopah Indian Reservation	5,146.27
Arizona	PPR	United States (Cocopah Indian Tribe)	763.80
Arizona	PPR	Fort Mojave Indian Reservation	40,805.64
Arizona	PPR	Fort Mojave Indian Reservation	15,103.26
Arizona	PPR	Fort Yuma Indian Reservation	4,000.50
Arizona	PPR	Colorado River Indian Reservation	27,032.72
Arizona	PPR	Colorado River Indian Reservation	131,048.32
Arizona	PPR	Colorado River Indian Reservation	186,368.00
-	-	**Subtotal**	**1,042,564.61**
California	PPR	Chemehuevi Indian Reservation	6,123.60
California	PPR	Fort Mojave Indian Reservation	9,028.80
California	PPR	Fort Yuma Indian Reservation	36,524.16
California	PPR	Colorado River Indian Reservation	3,398.80
California	PPR	Colorado River Indian Reservation	23,339.78
California	PPR	Colorado River Indian Reservation	6,232.10
-	-	**Subtotal**	**84,647.24**
Nevada	P1 (PPR)	Fort Mojave Indian Reservation	8,397.78
-	-	**Subtotal**	**8,397.78**
-	-	**Total**	**1,135,609.63**

*CAP allocations are shown as mainstream consumptive use equivalents, with 5 percent for CAP system loss added to the Contract volume.

** May at some time be diverted from the Colorado River above Lake Mead.

C.7.2 Present Perfected Rights Assumptions for the Priority Without Tribal Shortage Alternative Distribution Model

The entitlements in **Table C-31** below were removed from the PPR priority system emulated in this Alternative Distribution Model. Otherwise, PPRs are modeled as described for the Priority Shortage Allocation Model; the relative priorities of non-tribal PPRs based on Paragraph (5) of the Appendix to the Consolidated Decree in *Arizona v. California*, 547 U.S. 150 (2006), was not revisited in light of the tribal PPRs no longer being modeled as part of the PPR priority system.

Table C-31
PPRs Not Shorted Under Priority Without Tribal Shortage Alternative Distribution Model

Entitlement Holders	CU Equivalent (af)*	Diversion (af)	PPR No.	Date	Type of Use
Cocopah Indian Reservation	5,146	7,681	1	1917	Tribal
United States (Cocopah Indian Tribe)	764	1,140	8	1915	Tribal
Chemehuevi Indian Reservation	6,124	11,340	22	1907	Tribal
Fort Mojave Indian Reservation	40,806	75,566	3	1890	Tribal
Fort Mojave Indian Reservation	15,103	27,969	3	1890	Tribal
Fort Mojave Indian Reservation	9,029	16,720	25	1890	Tribal
Fort Mojave Indian Reservation	8,398	12,534	81	1890	Tribal
Fort Yuma Indian Reservation	36,524	71,616	23	1884	Tribal
Fort Yuma Indian Reservation	4,001	6,350	3a	1884	Tribal
Colorado River Indian Reservation	3,399	5,860	24	1876	Tribal
Colorado River Indian Reservation	27,033	51,986	2	1874	Tribal
Colorado River Indian Reservation	23,340	40,241	24	1874	Tribal
Colorado River Indian Reservation	131,048	252,016	2	1873	Tribal
Colorado River Indian Reservation	6,232	10,745	24	1873	Tribal
Colorado River Indian Reservation	186,368	358,400	2	1865	Tribal

*Calculated consumptive use equivalents. Historical Decree Accounting data were used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS. For purposes of modeling, these values are assumed to be generally representative of return flow conditions for the specified users, and match CRSS inputs. Those ratios were used to estimate the consumptive use equivalent of diversion entitlements. In CA, miscellaneous PPRs were assumed to have a CU/Div ratio of .64. For IID, consumptive use was assumed to equal diversion since the CU/diversion ratio based on average historical efficiency was 0.996. In AZ, with limited supporting data about miscellaneous PPRs, they were assumed to be fully consumptive. Where an entitlement was quantified on the basis of CU by the Consolidated Decree, those values are used.

Table C-32 on the following page summarizes the non-tribal PPRs remaining in each state, which informs the distribution of water among the Lower Division States as described in the next section.

Table C-32
Summary of Non-Tribal PPRs Remaining in Each State in the Priority Without Tribal Shortage Alternative Distribution Model

State Summary	CU Equivalent Entitlement (af)	Diversion Entitlement (af)
Arizona Total	187,542.80	296,863.00
California Total	2,716,678.90	2,863,051.00
Nevada Total	300.00	500.00
Total	**2,904,521.70**	**3,160,414.00**

C.7.3 Distribution Among States for the Priority Without Tribal Shortage Alternative Distribution Model

The distribution of water among the Lower Division States in this Alternative Distribution Model is similar to the Priority Shortage Allocation Model except as described below.

Generally, state apportionments in excess of PPRs and tribal entitlements are set as co-equal, except that Arizona bears California's share of shortage until the remaining (non-tribal) Arizona Fourth Priority is exhausted.

C.7.3.1 Stage 1, 2, and 3 Shortage Assumptions

In developing the Stage 1 and Stage 2 percentages for the sharing of shortage among the Lower Division States in this Alternative Distribution Model, the consumptive use (or equivalent) of non-tribal PPR entitlements and tribal entitlements were removed from the apportionment volumes in each ratio, as detailed below.

In Stage 1 of this Alternative Distribution Model, shortages are imposed only upon Arizona and Nevada, continuing until the deliveries to non-tribal post-1968 (P4) water entitlement holders in Arizona (including CAP subcontractors) are reduced to zero. Based on modeled full use by P1-3 entitlements in Arizona, and no shortage to Tribes as assumed in this Alternative Distribution Model, approximately 821,834 afy of shortage to Arizona (or 1,978,166 afy of water available to Arizona) exhausts the P4 supply. Stage 1 shortage ends at that point.

The Stage 1 shortage sharing percentages for the Priority Without Tribal Shortage Alternative Distribution Model are computed as follows:

- Nevada bears a reduction of about 8 percent of the total Lower Division States shortage volume, computed as a ratio of Nevada's apportionment less non-tribal PPR and tribal consumptive use (or equivalent) entitlements within Nevada over the sum of the apportionments of the Lower Division States less all non-tribal PPR and tribal consumptive use (or equivalent) entitlements
    - (300 kaf – 300 af - 8,398 af) / (7.5 maf – 1,135,610 af – 2,904,522 af) = 8.42 percent
- Arizona bears the remainder of the total Lower Division States shortage volume (91.58 percent)

The Stage 2 distribution of water among the Lower Division States in this Alternative Distribution Model begins at the end of Stage 1 and ends at the volume of total shortage where reductions to non-tribal PPRs are necessary; at that point, water available to each state equals the consumptive use (or equivalent) of non-tribal PPR entitlements and tribal entitlements within the state.

Stage 2 shortage is the amount of additional shortage above the Stage 1 shortage volume, and the additional shortage is distributed according to the Stage 2 ratios.

The Stage 2 shortage sharing percentages are computed as follows, with the non-tribal PPR and tribal entitlement volumes the same as in the Stage 1 ratios.

- Nevada bears about 8 percent of the Stage 2 shortage in addition to its Stage 1 shortage, computed as a ratio of Nevada's apportionment less non-tribal PPRs and tribal entitlements in Nevada less the amount of shortage applied to Nevada under Stage 1, over the sum of the apportionments of the Lower Division States less total non-tribal PPRs and tribal entitlements less the total amount shorted to users under Stage 1
    - (0.3 maf – NV non-tribal PPRs – NV tribal entitlements - NV Stage 1 shortage) / (7.5 maf – total non-tribal PPRs – total tribal entitlements - total Stage 1 shortage) or
        - (300,000 – 300 - 8,398 – 75,555) / (7,500,000 – 2,904,522 – 1,135,610 – 897,389) = 8.42 percent
- Arizona bears about 29 percent of the Stage 2 shortage in addition to its Stage 1 shortage, computed as a ratio of Arizona's apportionment less non-tribal PPRs and tribal entitlements in Arizona less the amount of shortage applied to Arizona under Stage 1, over the sum of the apportionments of the Lower Division States less total non-tribal PPRs and tribal entitlements less the total amount shorted to users under Stage 1
    - (2.8 maf – AZ non-tribal PPRs – AZ tribal entitlements - AZ Stage 1 shortage) / (7.5 maf – total non-tribal PPRs – total tribal entitlements - total Stage 1 shortage) or
        - (2,800,000 – 187,543 – 1,042,565 – 821,834) / (7,500,000 – 2,716,679 – 1,135,610 – 897,389) = 29.19 percent
- California bears about 62 percent of the Stage 2 shortage, computed as a ratio of California's apportionment less non-tribal PPRs and tribal entitlements in California, over the sum of the apportionments of the Lower Division States less total non-tribal PPRs and tribal entitlements less the total amount shorted to users under Stage 1
    - (4.4 maf – CA non-tribal PPRs – CA tribal entitlements) / (7.5 maf – total non-tribal PPRs – total tribal entitlements - total Stage 1 shortage) or
        - (4,400,000 – 2,716,679 – 84,647) / (7,500,000 - 2,716,679 – 1,135,610 – 897,389) = 62.39 percent

The distribution of water among non-tribal PPRs is characterized as Stage 3, where water available to each state is an aggregation of the non-tribal PPR volumes within the state that could be filled at a given level of shortage, and tribal entitlements within the states.

Table C-33 below summarizes the distribution of shortage and available water to the Lower Division States under the Priority Without Tribal Shortage Alternative Distribution Model. Total shortage volumes include an assumed component for Mexico, as described in the sections that follow, and will not sum across rows.

Table C-33
Summary of Shortage Volumes and Available Water by Lower Division State Under the Priority Without Tribal Shortage Alternative Distribution Model (af)

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
0	0	2,800,000	0	4,400,000	0	300,000
(10,000)	(7,632)	2,792,368	0	4,400,000	(702)	299,298
(35,000)	(26,711)	2,773,289	0	4,400,000	(2,456)	297,544
(65,000)	(49,606)	2,750,394	0	4,400,000	(4,561)	295,439
(80,000)	(61,054)	2,738,946	0	4,400,000	(5,613)	294,387
(100,000)	(76,317)	2,723,683	0	4,400,000	(7,016)	292,984
(140,000)	(106,844)	2,693,156	0	4,400,000	(9,823)	290,177
(200,000)	(152,634)	2,647,366	0	4,400,000	(14,032)	285,968
(300,000)	(228,951)	2,571,049	0	4,400,000	(21,049)	278,951
(360,000)	(274,742)	2,525,258	0	4,400,000	(25,258)	274,742
(399,600)	(304,963)	2,495,037	0	4,400,000	(28,037)	271,963
(400,000)	(305,268)	2,494,732	0	4,400,000	(28,065)	271,935
(480,000)	(366,322)	2,433,678	0	4,400,000	(33,678)	266,322
(500,400)	(381,891)	2,418,109	0	4,400,000	(35,109)	264,891
(600,000)	(457,903)	2,342,097	0	4,400,000	(42,097)	257,903
(720,000)	(549,483)	2,250,517	0	4,400,000	(50,517)	249,483
(700,000)	(534,220)	2,265,780	0	4,400,000	(49,114)	250,886
(800,000)	(610,537)	2,189,463	0	4,400,000	(56,130)	243,870
(840,000)	(641,064)	2,158,936	0	4,400,000	(58,936)	241,064
(900,000)	(686,854)	2,113,146	0	4,400,000	(63,146)	236,854
(960,000)	(732,644)	2,067,356	0	4,400,000	(67,356)	232,644
(1,000,000)	(763,171)	2,036,829	0	4,400,000	(70,162)	229,838
(1,076,867)	(821,834)	1,978,166	0	4,400,000	(75,555)	224,445
(1,100,000)	(827,462)	1,972,538	(12,027)	4,387,973	(77,178)	222,822
(1,200,000)	(851,789)	1,948,211	(64,017)	4,335,983	(84,195)	215,805
(1,230,000)	(859,087)	1,940,913	(79,613)	4,320,387	(86,299)	213,701
(1,320,000)	(880,982)	1,919,018	(126,404)	4,273,596	(92,614)	207,386

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(1,375,000)	(894,362)	1,905,638	(154,999)	4,245,001	(96,473)	203,527
(1,440,000)	(910,174)	1,889,826	(188,792)	4,211,208	(101,034)	198,966
(1,500,000)	(924,771)	1,875,229	(219,986)	4,180,014	(105,243)	194,757
(1,530,000)	(932,069)	1,867,931	(235,583)	4,164,417	(107,348)	192,652
(1,600,000)	(949,098)	1,850,902	(271,976)	4,128,024	(112,259)	187,741
(1,680,000)	(968,560)	1,831,440	(313,568)	4,086,432	(117,872)	182,128
(1,800,000)	(997,753)	1,802,247	(375,955)	4,024,045	(126,292)	173,708
(1,920,000)	(1,026,945)	1,773,055	(438,343)	3,961,657	(134,711)	165,289
(2,000,000)	(1,046,407)	1,753,593	(479,935)	3,920,065	(140,324)	159,676
(2,040,000)	(1,056,138)	1,743,862	(500,731)	3,899,269	(143,131)	156,869
(2,100,000)	(1,070,735)	1,729,265	(531,925)	3,868,075	(147,341)	152,659
(2,200,000)	(1,095,062)	1,704,938	(583,915)	3,816,085	(154,357)	145,643
(2,280,000)	(1,114,524)	1,685,476	(625,506)	3,774,494	(159,970)	140,030
(2,300,000)	(1,119,389)	1,680,611	(635,904)	3,764,096	(161,373)	138,627
(2,400,000)	(1,143,717)	1,656,283	(687,894)	3,712,106	(168,389)	131,611
(2,600,000)	(1,192,371)	1,607,629	(791,874)	3,608,126	(182,422)	117,578
(2,700,000)	(1,216,698)	1,583,302	(843,864)	3,556,136	(189,438)	110,562
(2,880,000)	(1,260,488)	1,539,512	(937,445)	3,462,555	(202,067)	97,933
(3,000,000)	(1,289,680)	1,510,320	(999,833)	3,400,167	(210,486)	89,514
(3,120,000)	(1,318,873)	1,481,127	(1,062,221)	3,337,779	(218,906)	81,094
(3,240,000)	(1,348,066)	1,451,934	(1,124,609)	3,275,391	(227,325)	72,675
(3,360,000)	(1,377,259)	1,422,741	(1,186,996)	3,213,004	(235,745)	64,255
(3,480,000)	(1,406,451)	1,393,549	(1,249,384)	3,150,616	(244,164)	55,836
(3,500,000)	(1,411,317)	1,388,683	(1,259,782)	3,140,218	(245,568)	54,432
(3,600,000)	(1,435,644)	1,364,356	(1,311,772)	3,088,228	(252,584)	47,416
(3,720,000)	(1,464,837)	1,335,163	(1,374,160)	3,025,840	(261,003)	38,997
(3,750,000)	(1,472,135)	1,327,865	(1,389,757)	3,010,243	(263,108)	36,892
(3,840,000)	(1,494,030)	1,305,970	(1,436,548)	2,963,452	(269,423)	30,577
(3,850,000)	(1,496,462)	1,303,538	(1,441,747)	2,958,253	(270,124)	29,876
(3,960,000)	(1,523,223)	1,276,777	(1,498,935)	2,901,065	(277,842)	22,158
(4,000,000)	(1,532,953)	1,267,047	(1,519,731)	2,880,269	(280,649)	19,351
(4,080,000)	(1,552,415)	1,247,585	(1,561,323)	2,838,677	(286,262)	13,738
(4,151,843)	(1,569,893)	1,230,107	(1,598,674)	2,801,326	(291,302)	8,698
(5,000,000)	(1,751,446)	1,048,554	(2,123,618)	2,276,382	(291,602)	8,398
(6,000,000)	(1,751,446)	1,048,554	(2,956,952)	1,443,048	(291,602)	8,398
(7,000,000)	(1,751,446)	1,048,554	(3,790,285)	609,715	(291,602)	8,398
(7,500,000)	(1,751,446)	1,048,554	(4,206,952)	193,048	(291,602)	8,398
(7,637,268)	(1,757,435)	1,042,565	(4,315,353)	84,647	(291,602)	8,398

C.7.4 Distribution Within States for the Priority Without Tribal Shortage Alternative Distribution Model

C.7.4.1 Introduction

The distribution of water within the Lower Division States in this Alternative Distribution Model is consistent with the Priority Shortage Allocation Model except as described below. The differences arise from a need to adjust the priority system so that it functions without the tribal entitlements that are modeled as fully satisfied.

C.7.4.2 General State Assumptions

General state assumptions are as described in the Priority Shortage Allocation Model.

C.7.4.3 Nevada Assumptions

In this Alternative Distribution Model, the Nevada priority system was adjusted to reflect 300 afy of non-tribal PPR entitlements, and 8,398 afy of tribal entitlements, limiting the shortage that could be applied to Nevada to 291,602 afy. This does not represent a functional change to the distribution of water within Nevada in comparison to the Priority Shortage Allocation Model, as the single tribal entitlement was also the highest-priority PPR in the state.

C.7.4.4 California Assumptions

In this Alternative Distribution Model, the California priority system was adjusted to reflect 2,716,679 afy of non-tribal PPR entitlements, and 84,647 afy of tribal entitlements, limiting the shortage that could be applied to California to 4,315,353 afy. This represents a very limited change to the distribution of water within California in comparison to the Priority Shortage Allocation Model, as tribal entitlements in California are all PPRs and mostly senior to the non-tribal PPRs in the state.

C.7.4.5 Arizona Assumptions

In this Alternative Distribution Model, the Arizona priority system was adjusted to reflect 187,543 afy of non-tribal PPR entitlements, and 1,042,565 afy of tribal entitlements, limiting the shortage that could be applied to Arizona to 1,757,435 afy. This represents a significant change to the distribution of water within Arizona in comparison to the Priority Shortage Allocation Model, as tribal entitlements in Arizona are part of every priority pool in the state, but with limited effect on tribal PPRs which are already mostly senior to the non-tribal PPRs in the state.

C.7.4.5.1 Arizona Priority Two and Three Assumptions

In this Alternative Distribution Model, the Ak-Chin Indian Community's Priority Three entitlement was removed from its position among the "Various Entitlements" as described for the Priority Shortage Allocation Model, changing the ratios for the distribution of water among those entitlements, and changing the size of Priorities Two and Three in total from 798,059 afy to 748,059 afy. This results in a given volume of shortage to Priorities Two and Three being shared across a smaller pool of users.

C.7.4.5.2 Arizona Priority Four Assumptions

The most significant differences in this Alternative Distribution Model in comparison to the Priority Shortage Allocation Model result from adjustments to Priority Four assumptions. The Arizona Fourth Priority shortage sharing procedure was revised to be consistent with other assumptions for this Alternative Distribution Model. It subtracts: 1) tribal entitlements not shorted, 2) non-tribal PPR entitlements, 3) non-tribal Priority Two and Three entitlements, and 4) the Arizona shortage volume (all on a consumptive use basis) from Arizona's Colorado River water apportionment to derive the fourth priority supply on a consumptive use basis.

The P4(i) available supply is calculated as 11 percent[27] of the fourth priority supply on a consumptive use basis, not to exceed the total of the consumptive use equivalents of entitlements in the P4(i) pool (90,833 afy as modeled). The remainder of the fourth priority supply is available for diversion as fourth priority water by the CAP to fulfill CAP subcontracts.

The calculation of Available CAP Supply is adjusted so that system loss associated with the Fourth Priority is given as 5 percent of the subcontract volumes remaining in the intra-CAP priority system, which are filled by the Available CAP Supply.

P4(i) (Mainstream) Framework and Assumptions

In this Alternative Distribution Model, the following modeled entitlements were removed from the P4(i) pool: Cocopah Indian Reservation, Hopi Tribe, Water Reserved by the Secretary for a Navajo-Hopi Settlement, and Unallocated 4th Priority Mainstream Water. This changes the size of the pool on a diversion basis from 164,652 afy to 144,618 afy, thereby changing the ratios for the distribution of water among those entitlements and resulting in a given volume of shortage to P4(i) being shared across a smaller pool of users.

CAP Framework and Assumptions

This Alternative Distribution Model differs from the Priority Shortage Allocation Model in the constituents of the CAP NIA-B, NIA-A, M&I, and Indian Priorities. The differences are so significant as to render the existing intra-CAP priority system inoperable; one possible approach is reflected in the model so as to complete the modeling exercise, but is not a legal position or proposal.

Eleven modeled entitlements were removed from the CAP Indian Priority pool, leaving a single Indian Priority entitlement of 500 afy (out of 343,079 afy) currently held by a non-tribal entity. One modeled entitlement of 18,145 afy (San Carlos Apache Tribe) was removed from the CAP M&I Priority pool (out of 638,823 afy). Contractual provisions for the distribution of Available CAP Supply between the Indian and M&I Priority pools do not function under these assumptions; accordingly, in recognition of the co-equal nature of the Indian and M&I Priority pools, they were consolidated into a simulated single CAP first priority in this Alternative Distribution Model, totaling 621,178 afy. Water available to this consolidated pool (the first 621,178 afy of Available

[27] Calculated as 90,833 afy divided by 844,745 afy, the ratio of the adjusted P4(i) contracting pool to the sum of the adjusted P4(i) and P4(ii) contracting pools.

CAP Supply) is distributed among the subcontractors in proportion to their subcontract volumes relative to the total.

NIA Priority supply is calculated as the remaining Available CAP Supply above the 621,178 afy necessary to fill the consolidated Indian and M&I first priority. White Mountain Apache Tribe's entitlement was removed from the NIA-B pool, and the following three entitlements were removed from the NIA-A pool: Gila River Indian Community, Tohono O'odham - Schuk Toak & San Xavier, and Hualapai Tribe. NIA Priority supply is used to fill the remaining NIA-A subcontracts first, then fills the NIA-B subcontracts if supply allows, each in proportion to the subcontract volumes relative to the adjusted totals.

CAP system loss associated with the tribal entitlements removed from the CAP priority pools is included in relevant calculations as 5 percent added to the contract volume.

C.7.5 Priority Without Tribal Shortage Alternative Distribution Model Results

The tables in this section present the results of the Priority Without Tribal Shortage Alternative Distribution Model over a range of total shortages to the Lower Basin including Mexico.

Table C-34, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-35, the Tribal Summary, presents the shortage impacts on tribes.

Table C-36, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-37, the Domestic Summary, presents the shortage impacts on domestic users

Table C-34
Priority Without Tribal Shortage Alternative Distribution Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
Arizona	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion	407,102	678,791	731,287	731,001	731,001	731,001	731,001	731,001	731,001	731,001	731,001
-	NIA Priority[2]	96,833	96,833	96,833	96,833	96,833	96,833	96,833	96,833	96,833	96,833	96,833
-	M&I and Indian Priorities[2]	326,037	597,726	621,178	621,178	621,178	621,178	621,178	621,178	621,178	621,178	621,178
-	4th Priority i (Mainstream)	50,801	84,380	90,833	90,833	90,833	90,833	90,833	90,833	90,833	90,833	90,833
-	2nd & 3rd Priorities	0	0	102,650	175,919	224,573	248,901	297,555	467,846	589,483	711,120	748,059
-	1st Priority (Present Perfected Rights)	0	0	0	0	0	0	0	0	0	0	181,554
-	**Subtotal**	**457,903**	**763,171**	**924,771**	**997,753**	**1,046,407**	**1,070,735**	**1,119,389**	**1,289,680**	**1,411,317**	**1,532,953**	**1,751,446**
California	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	0	0	219,986	375,955	388,002	388,002	388,002	388,002	388,002	388,002	388,002
-	3rd Priority (IID, CVWD, PVID)	0	0	0	0	91,933	143,923	247,903	611,831	835,000	835,000	835,000
-	2nd Priority (Yuma Project Reservation Division)	0	0	0	0	0	0	0	0	7,294	7,294	7,294
-	1st Priority (PVID)	0	0	0	0	0	0	0	0	29,486	289,435	368,378
-	Present Perfected Rights (PPRs)	0	0	0	0	0	0	0	0	0	0	524,944
-	**Subtotal**	**0**	**0**	**219,986**	**375,955**	**479,935**	**531,925**	**635,904**	**999,833**	**1,259,782**	**1,519,731**	**2,123,618**
Nevada	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	42,097	70,162	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717
-	8th Priority (SNWA & Big Bend)	0	0	12,527	33,575	47,608	54,624	68,656	117,770	152,851	162,980	162,980
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	0	0	0	0	0	0	0	0	0	2,257	2,257
-	6th Priority (Las Vegas Valley Water District)	0	0	0	0	0	0	0	0	0	8,012	8,012
-	5th Priority (PABCO)	0	0	0	0	0	0	0	0	0	483	483
-	4th Priority (Henderson & Basic)	0	0	0	0	0	0	0	0	0	14,201	20,299
-	3rd Priority (Boulder City)	0	0	0	0	0	0	0	0	0	0	3,056

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	2nd Priority (Lake Mead National Rec Area)	0	0	0	0	0	0	0	0	0	0	1,500
-	1st Priority (LMNRA PPR)	0	0	0	0	0	0	0	0	0	0	300
-	**Subtotal**	**42,097**	**70,162**	**105,243**	**126,292**	**140,324**	**147,341**	**161,373**	**210,486**	**245,568**	**280,649**	**291,602**
-	**Lower Division States Subtotal**	**500,000**	**833,333**	**1,250,000**	**1,500,000**	**1,666,667**	**1,750,000**	**1,916,667**	**2,500,000**	**2,916,667**	**3,333,333**	**4,166,667**
Mexico	**Mexico Subtotal**	**100,000**	**166,667**	**250,000**	**300,000**	**333,333**	**350,000**	**383,333**	**500,000**	**583,333**	**666,667**	**833,333**
	Total	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here

[2]These estimated shortages to priorities within the CAP reflect the effect of CAP system loss, and do not total to CAP shortage at the point of diversion.

Disclaimer: These modeling results for the Priority (w/o Tribal Shortage) Alternative Distribution Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Volumes of total shortage include a portion modeled as attributed to Mexico, but that portion is not itemized in summary sheets.

Table C-35
Priority Without Tribal Shortage Alternative Distribution Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	San Carlos Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tonto Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Yavapai Apache Nation	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP M&I Priority	San Carlos Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
4(i)	Hopi Tribe[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
4(i)	Cocopah Indian Reservation	Yuma County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	0	0	0	0	0	0	0	0	0	0	0
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
3	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
California			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	Gila County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	0	0	0	0	0	0	0	0	0	0	0
-	Maricopa County	-	0	0	0	0	0	0	0	0	0	0	0
-	Mohave County	-	0	0	0	0	0	0	0	0	0	0	0
-	Pima County	-	0	0	0	0	0	0	0	0	0	0	0
-	Pinal County	-	0	0	0	0	0	0	0	0	0	0	0
-	Yuma County	-	0	0	0	0	0	0	0	0	0	0	0
-	Apache County	-	0	0	0	0	0	0	0	0	0	0	0
-	Navajo County	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Arizona Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
-	Riverside	-	-	-	-	-	-	-	-	-	-	-	-
-	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands).

Disclaimer: These modeling results for the Priority (w/o Tribal Shortage) Alternative Distribution Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Table C-36
Priority Without Tribal Shortage Alternative Distribution Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	997	1,656	1,783	1,783	1,783	1,783	1,783	1,783	1,783	1,783	1,783
4(i)	Arizona State Land Department	Yuma County	2,321	3,855	4,150	4,150	4,150	4,150	4,150	4,150	4,150	4,150	4,150
4(i)	Beattie Farms, Southwest	Yuma County	390	648	697	697	697	697	697	697	697	697	697
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	148	245	264	264	264	264	264	264	264	264	264
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	44	74	79	79	79	79	79	79	79	79	79
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	738	1,225	1,319	1,319	1,319	1,319	1,319	1,319	1,319	1,319	1,319
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	76	126	136	136	136	136	136	136	136	136	136
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	2,614	4,342	4,675	4,675	4,675	4,675	4,675	4,675	4,675	4,675	4,675
4(i)	Curtis, Armon	Yuma County	105	175	188	188	188	188	188	188	188	188	188
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	504	837	901	901	901	901	901	901	901	901	901
4(i)	Matador Farms, LLC	La Paz County	1,581	2,626	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826
4(i)	JRJ Partners, L.L.C.	Yuma County	379	630	678	678	678	678	678	678	678	678	678
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	12,316	20,456	22,021	22,021	22,021	22,021	22,021	22,021	22,021	22,021	22,021
4(i)	North Baja Pipeline, LLC[2]	La Paz County	169	280	301	301	301	301	301	301	301	301	301
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	325	539	580	580	580	580	580	580	580	580	580
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	169	280	301	301	301	301	301	301	301	301	301
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	171	284	305	305	305	305	305	305	305	305	305
4(i)	Red River Land Company, LLC	La Paz County	105	175	188	188	188	188	188	188	188	188	188

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Phillips, Milton and Jean	Yuma County	21	35	38	38	38	38	38	38	38	38	38
4(i)	Western Water, LLC	La Paz County	188	313	337	337	337	337	337	337	337	337	337
3	Sturges, Harold	Yuma County	0	0	335	335	335	335	335	335	335	335	335
3	Sturges, Irma	Yuma County	0	0	385	385	385	385	385	385	385	385	385
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	0	0	7,535	22,693	32,798	37,850	47,955	83,322	108,585	133,847	141,519
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	0	0	3,582	10,788	15,592	17,994	22,798	39,611	51,621	63,631	67,278
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	0	0	358	1,079	1,560	1,800	2,281	3,963	5,165	6,366	6,731
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	0	0	19,552	48,790	68,282	78,028	97,520	165,742	214,471	263,201	278,000
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	0	0	252	629	880	1,006	1,257	2,136	2,764	3,392	3,582
3	Yuma County Water Users' Association (14,701af M&I includes YAO's 489.95af conversion)[2,3]	Yuma County	0	0	5,440	13,796	19,367	22,152	27,723	47,221	61,148	75,075	79,304
3	University of Arizona	Yuma County	0	0	922	1,088	1,088	1,088	1,088	1,088	1,088	1,088	1,088
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	0	0	0	120	120	120	120	120	120	120	120
3	Unit B Irrigation & Drainage District[3]	Yuma County	0	0	0	1,762	3,049	3,692	4,978	9,479	12,694	15,910	16,886
1	PPR No. 15, Molina	Yuma County	0	0	0	0	0	0	0	0	0	0	318
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	0	0	0	0	0	0	0	0	0	0	445
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	0	0	0	0	0	0	0	0	0	0	4,352
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	0	0	0	0	0	0	0	0	0	0	6,125
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	0	0	0	0	0	0	0	0	0	0	170,314
1	PPR No. 7, Powers	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 10, Hulet (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 12, Miller (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 18, Swan (MVIDD)	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**23,360**	**38,801**	**80,130**	**143,234**	**185,224**	**206,218**	**248,208**	**395,171**	**500,145**	**605,119**	**818,551**
California			**-**	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	0	0	0	0	550	862	1,484	3,664	5,000	5,000	5,000
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	0	0	0	0	91,383	143,061	246,418	330,000	330,000	330,000	330,000
3	Imperial Irrigation District (IID) (3a)	Imperial County	0	0	0	0	0	0	0	278,168	500,000	500,000	500,000
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	0	0	0	0	0	0	0	0	7,294	7,294	7,294
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	0	0	0	0	0	0	0	0	29,486	289,435	368,378
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	0	0	0	0	0	0	0	0	0	0	115
PPR	PPR No. 41, Chagnon	San Bernardino	0	0	0	0	0	0	0	0	0	0	77
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	0	0	0	0	0	0	0	0	0	0	61
PPR	PPR No. 34, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	69
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	0	0	0	0	0	0	0	0	0	0	19,518
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	0	0	0	0	0	0	0	0	0	0	504,896
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 42, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 37, Milpitas	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 33, Morgan	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 35, Simons	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**91,933**	**143,923**	**247,903**	**611,831**	**871,780**	**1,131,729**	**1,735,408**
Nevada			**-**	-	-	-	-	-	-	-	-	-	-
None	None		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**23,360**	**38,801**	**80,130**	**143,234**	**277,157**	**350,141**	**496,110**	**1,007,002**	**1,371,925**	**1,736,848**	**2,553,959**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	5,922	9,837	10,589	10,589	10,589	10,589	10,589	10,589	10,589	10,589	10,589
-	Mohave County	-	12,316	20,456	22,021	22,021	22,021	22,021	22,021	22,021	22,021	22,021	22,021
-	Yuma County	-	5,122	8,508	47,520	110,624	152,614	173,609	215,598	362,561	467,535	572,509	785,941
-	**Subtotal Arizona Irrigation**	-	**23,360**	**38,801**	**80,130**	**143,234**	**185,224**	**206,218**	**248,208**	**395,171**	**500,145**	**605,119**	**818,551**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	0	0	0	0	91,933	143,923	247,903	333,664	349,743	479,718	519,189
-	Imperial County	-	0	0	0	0	0	0	0	278,168	522,037	652,012	1,216,081
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	138
-	**Subtotal California Irrigation**	-	**0**	**0**	**0**	**0**	**91,933**	**143,923**	**247,903**	**611,831**	**871,780**	**1,131,729**	**1,735,408**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Disclaimer: These modeling results for the Priority (w/o Tribal Shortage) Alternative Distribution Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Table C-37
Priority Without Tribal Shortage Alternative Distribution Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786	2,786
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185	18,185
CAP NIA-B	Carefree Water Company	Maricopa County	112	112	112	112	112	112	112	112	112	112	112
CAP NIA-B	Cave Creek	Maricopa County	386	386	386	386	386	386	386	386	386	386	386
CAP NIA-B	El Mirage	Maricopa County	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217	3,217
CAP NIA-B	Freeport	Pima County	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678	5,678
CAP NIA-B	Gilbert	Maricopa County	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832	1,832
CAP NIA-B	Marana	Pima County	515	515	515	515	515	515	515	515	515	515	515
CAP NIA-B	Queen Creek	Maricopa County	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162	4,162
CAP NIA-B	Resolution Copper	Maricopa County	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238	2,238
CAP NIA-B	Rosemont Copper	Pima County	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124
CAP NIA-B	SRP	Maricopa County	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	817	817	817	817	817	817	817	817	817	817	817
CAP NIA-A	Phoenix	Maricopa County	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280	37,280
CAP NIA-A	Chandler	Maricopa County	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924	3,924
CAP NIA-A	Gilbert	Maricopa County	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537	1,537
CAP NIA-A	Glendale	Maricopa County	682	682	682	682	682	682	682	682	682	682	682
CAP NIA-A	Mesa	Maricopa County	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551	5,551

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Scottsdale	Maricopa County	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306	3,306
CAP NIA-A	Tempe	Maricopa County	23	23	23	23	23	23	23	23	23	23	23
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	262	481	500	500	500	500	500	500	500	500	500
CAP M&I	ASARCO	Pima County	11,022	20,207	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000
CAP M&I	Avondale	Maricopa County	2,843	5,212	5,416	5,416	5,416	5,416	5,416	5,416	5,416	5,416	5,416
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	14,789	27,112	28,176	28,176	28,176	28,176	28,176	28,176	28,176	28,176	28,176
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	4,663	8,549	8,884	8,884	8,884	8,884	8,884	8,884	8,884	8,884	8,884
CAP M&I	Arizona Water Company, Coolidge	Pinal County	1,050	1,924	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
CAP M&I	Arizona Water Company, Superstition	Pinal County	3,299	6,048	6,285	6,285	6,285	6,285	6,285	6,285	6,285	6,285	6,285
CAP M&I	Arizona Water Company, White Tank	Maricopa County	508	931	968	968	968	968	968	968	968	968	968
CAP M&I	Buckeye	Maricopa County	36	65	68	68	68	68	68	68	68	68	68
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	3,373	6,183	6,426	6,426	6,426	6,426	6,426	6,426	6,426	6,426	6,426
CAP M&I	Carefree Water Company	Maricopa County	881	1,615	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678
CAP M&I	Cave Creek	Maricopa County	1,169	2,144	2,228	2,228	2,228	2,228	2,228	2,228	2,228	2,228	2,228
CAP M&I	Chandler	Maricopa County	4,542	8,327	8,654	8,654	8,654	8,654	8,654	8,654	8,654	8,654	8,654
CAP M&I	Chaparral City Water Company	Maricopa County	4,676	8,573	8,909	8,909	8,909	8,909	8,909	8,909	8,909	8,909	8,909
CAP M&I	Circle City	Maricopa County	2,064	3,784	3,932	3,932	3,932	3,932	3,932	3,932	3,932	3,932	3,932
CAP M&I	El Mirage	Maricopa County	267	489	508	508	508	508	508	508	508	508	508
CAP M&I	Eloy	Pinal County	1,139	2,089	2,171	2,171	2,171	2,171	2,171	2,171	2,171	2,171	2,171
CAP M&I	EPCOR, Agua Fria	Maricopa County	5,822	10,674	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093
CAP M&I	EPCOR, Paradise Valley	Maricopa County	1,696	3,109	3,231	3,231	3,231	3,231	3,231	3,231	3,231	3,231	3,231
CAP M&I	EPCOR, Sun City	Maricopa County	2,199	4,031	4,189	4,189	4,189	4,189	4,189	4,189	4,189	4,189	4,189

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	EPCOR, Sun City West	Maricopa County	1,245	2,282	2,372	2,372	2,372	2,372	2,372	2,372	2,372	2,372	2,372
CAP M&I	Florence	Pinal County	1,075	1,971	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048
CAP M&I	Freeport-Miami	Gila County	1,525	2,796	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	1,498	2,746	2,854	2,854	2,854	2,854	2,854	2,854	2,854	2,854	2,854
CAP M&I	Gilbert	Maricopa County	3,797	6,962	7,235	7,235	7,235	7,235	7,235	7,235	7,235	7,235	7,235
CAP M&I	Glendale	Maricopa County	9,047	16,585	17,236	17,236	17,236	17,236	17,236	17,236	17,236	17,236	17,236
CAP M&I	Goodyear	Maricopa County	5,638	10,336	10,742	10,742	10,742	10,742	10,742	10,742	10,742	10,742	10,742
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	34	62	64	64	64	64	64	64	64	64	64
CAP M&I	Green Valley Community Water Company	Pima County	1,500	2,750	2,858	2,858	2,858	2,858	2,858	2,858	2,858	2,858	2,858
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	997	1,828	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
CAP M&I	Marana	Pima County	1,226	2,248	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	349	640	665	665	665	665	665	665	665	665	665
CAP M&I	Mesa	Maricopa County	22,833	41,861	43,503	43,503	43,503	43,503	43,503	43,503	43,503	43,503	43,503
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	7,065	12,952	13,460	13,460	13,460	13,460	13,460	13,460	13,460	13,460	13,460
CAP M&I	Oro Valley	Pima County	5,409	9,916	10,305	10,305	10,305	10,305	10,305	10,305	10,305	10,305	10,305
CAP M&I	Peoria	Maricopa County	14,235	26,097	27,121	27,121	27,121	27,121	27,121	27,121	27,121	27,121	27,121
CAP M&I	Phoenix	Maricopa County	66,188	121,343	126,104	126,104	126,104	126,104	126,104	126,104	126,104	126,104	126,104
CAP M&I	Pine	Gila County	85	155	161	161	161	161	161	161	161	161	161
CAP M&I	Queen Creek	Maricopa County	260	476	495	495	495	495	495	495	495	495	495
CAP M&I	Rio Verde Utilities	Maricopa County	426	781	812	812	812	812	812	812	812	812	812
CAP M&I	San Tan Irrigation District	Maricopa County	124	227	236	236	236	236	236	236	236	236	236
CAP M&I	Scottsdale	Maricopa County	27,718	50,816	52,810	52,810	52,810	52,810	52,810	52,810	52,810	52,810	52,810
CAP M&I	Spanish Trail Water Company	Pima County	1,594	2,922	3,037	3,037	3,037	3,037	3,037	3,037	3,037	3,037	3,037

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Surprise	Maricopa County	5,379	9,862	10,249	10,249	10,249	10,249	10,249	10,249	10,249	10,249	10,249
CAP M&I	Tempe	Maricopa County	2,265	4,152	4,315	4,315	4,315	4,315	4,315	4,315	4,315	4,315	4,315
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	37	68	71	71	71	71	71	71	71	71	71
CAP M&I	Tucson	Pima County	75,681	138,747	144,191	144,191	144,191	144,191	144,191	144,191	144,191	144,191	144,191
CAP M&I	Vail Water Company	Pima County	975	1,787	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,857
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	1,532	2,809	2,919	2,919	2,919	2,919	2,919	2,919	2,919	2,919	2,919
4(i)	Arizona State Land Department	Yuma County	539	895	963	963	963	963	963	963	963	963	963
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	32	53	57	57	57	57	57	57	57	57	57
4(i)	B&F Investment, LLC	La Paz County	21	35	38	38	38	38	38	38	38	38	38
4(i)	Bullhead City	Mohave County	5,343	8,875	9,553	9,553	9,553	9,553	9,553	9,553	9,553	9,553	9,553
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	751	1,248	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	2,459	4,084	4,397	4,397	4,397	4,397	4,397	4,397	4,397	4,397	4,397
4(i)	Bureau of Land Management	La Paz County	2,167	3,599	3,875	3,875	3,875	3,875	3,875	3,875	3,875	3,875	3,875
4(i)	Crystal Beach Water Conservation District	Mohave County	46	77	83	83	83	83	83	83	83	83	83
4(i)	Ehrenburg Improvement District	La Paz County	258	429	462	462	462	462	462	462	462	462	462
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	658	1,093	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	19	31	33	33	33	33	33	33	33	33	33
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	1	1	1	1	1	1	1	1	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	2	4	4	4	4	4	4	4	4	4	4.40
4(i)	Golden Shores Water Conservation District	Mohave County	703	1,167	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256
4(i)	GSC Farm, LLC	La Paz County	25	41	44	44	44	44	44	44	44	44	44
4(i)	Hillcrest Water Company	La Paz County	30	49	53	53	53	53	53	53	53	53	53

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Lake Havasu City	Mohave County	6,742	11,198	12,055	12,055	12,055	12,055	12,055	12,055	12,055	12,055	12,055
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	751	1,248	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	2,547	4,230	4,554	4,554	4,554	4,554	4,554	4,554	4,554	4,554	4,554
4(i)	La Paz County	La Paz County	123	204	220	220	220	220	220	220	220	220	220
4(i)	Martinez Lake Cabin Sites	Yuma County	8	13	14	14	14	14	14	14	14	14	14
4(i)	McAlister Family Trust	Mohave County	14	23	25	25	25	25	25	25	25	25	25
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	439	729	785	785	785	785	785	785	785	785	785
4(i)	Mohave Water Conservation District	Mohave County	632	1,050	1,131	1,131	1,131	1,131	1,131	1,131	1,131	1,131	1,131
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	1,054	1,750	1,884	1,884	1,884	1,884	1,884	1,884	1,884	1,884	1,884
4(i)	Parker, Town of[1]	La Paz County	362	601	647	647	647	647	647	647	647	647	647
4(i)	Quartzsite, Town of	La Paz County	376	624	672	672	672	672	672	672	672	672	672
4(i)	Queen Creek, Town of	Maricopa County	999	1,659	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,786
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	1	1	1	1	1	1	1	1	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	18	29	31	31	31	31	31	31	31	31	31
4(i)	Somerton, City of	Yuma County	263	438	471	471	471	471	471	471	471	471	471
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	35	58	63	63	63	63	63	63	63	63	63
4(i)	TV Marble Canyon AZ, LLC	Coconino County	25	41	44	44	44	44	44	44	44	44	44
3	City of Yuma[1]	Yuma County	0	0	48,522	48,522	48,522	48,522	48,522	48,522	48,522	48,522	48,522
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	0	0	25	25	25	25	25	25	25	25	25
3	Kaman, Inc.	Yuma County	0	0	2	2	2	2	2	2	2	2	2
3	Department of the Navy, MCAS	Yuma County	0	0	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
3	City of Yuma (cemetery)	Yuma County	0	0	60	60	60	60	60	60	60	60	60

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Mesa Fruit Growers' Association	Yuma County	0	0	15	15	15	15	15	15	15	15	15
3	Desert Lawn Memorial Park Association	Yuma County	0	0	138	138	138	138	138	138	138	138	138
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	301	751	1,051	1,201	1,501	2,551	3,300	4,050	4,278
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	476	1,187	1,661	1,898	2,372	4,031	5,217	6,402	6,762
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	211	527	737	842	1,052	1,789	2,314	2,840	3,000
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	194	484	678	775	968	1,645	2,129	2,613	2,760
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	352	878	1,228	1,403	1,754	2,981	3,857	4,734	5,000
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	7	18	25	28	35	60	77	95	100
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	0	0	7	18	25	28	35	60	77	95	100
3	Department of the Army - Yuma Proving Ground	Yuma County	0	0	79	198	277	317	396	673	871	1,069	1,129
3	Yuma Union High School District	Yuma County	0	0	148	148	148	148	148	148	148	148	148
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	0	0	82	248	248	248	248	248	248	248	248
2	Cibola National Wildlife Refuge	La Paz County	0	0	2,311	3,949	5,041	5,588	6,680	10,503	13,233	15,964	16,793
2	Lake Mead National Recreation Area	Mohave County	0	0	47	81	103	114	136	215	270	326	343
2	Bureau of Reclamation - Davis Dam	Mohave County	0	0	1	2	2	2	3	4	6	7	7
2	Imperial National Wildlife Refuge	La Paz County	0	0	3,165	5,409	6,905	7,653	9,149	14,385	18,124	21,864	23,000
2	Havasu Lake National Wildlife Refuge	Mohave County	0	0	5,146	8,795	11,227	12,444	14,876	23,390	29,471	35,552	37,399
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 20, Parker, City of	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 21, Yuma, City of	Yuma County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**450,311**	**740,138**	**831,365**	**841,529**	**848,194**	**851,527**	**858,192**	**881,520**	**898,182**	**914,845**	**919,905**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	0	0	219,986	375,955	388,002	388,002	388,002	388,002	388,002	388,002	388,002
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 30, Stephenson	San Bernardino	0	0	0	0	0	0	0	0	0	0	154
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	1

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 38, Andrade	San Bernardino	0	0	0	0	0	0	0	0	0	0	42
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	1
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 39, Reynolds	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 43, City of Needles	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**219,986**	**375,955**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,210**
Nevada			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	42,097	70,162	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717	92,717
8	Big Bend Water District	Clark	0	0	377	1,009	1,431	1,642	2,064	3,541	4,595	4,900	4,900
8	Robert B. Griffith Project	Clark	0	0	12,150	32,566	46,176	52,982	66,592	114,229	148,256	158,080	158,080
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	0	0	0	0	0	0	0	0	5	5
7	Bureau of Reclamation (includes Sportsman Park)	Clark	0	0	0	0	0	0	0	0	0	147	147
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	0	0	0	0	0	0	0	0	0	25	25
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	0	0	0	0	0	0	0	0	0	2,080	2,080
6	Las Vegas Valley Water District	Clark	0	0	0	0	0	0	0	0	0	8,012	8,012
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	0	0	0	0	0	0	0	0	0	483	483
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	2,986	4,268
4	City of Henderson	Clark	0	0	0	0	0	0	0	0	0	5,776	8,257
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	0	0	0	0	0	0	0	0	0	5,439	7,774

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for Priority w/o Tribal Shortage										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Boulder City	Clark	0	0	0	0	0	0	0	0	0	0	3,056
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	0	0	0	0	0	0	0	0	0	0	1,500
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	0	0	0	0	0	0	0	0	0	0	300
-	-	**Subtotal**	**42,097**	**70,162**	**105,243**	**126,292**	**140,324**	**147,341**	**161,373**	**210,486**	**245,568**	**280,649**	**291,602**
-	-	**Total**	**492,408**	**810,300**	**1,156,594**	**1,343,776**	**1,376,520**	**1,386,869**	**1,407,567**	**1,480,008**	**1,531,752**	**1,583,496**	**1,599,718**
	Summary by County												
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	25	41	44	44	44	44	44	44	44	44	44
-	Gila County	-	1,610	2,951	3,067	3,067	3,067	3,067	3,067	3,067	3,067	3,067	3,067
-	La Paz County	-	3,396	5,642	11,549	15,431	18,019	19,313	21,901	30,960	37,431	43,901	45,866
-	Maricopa County	-	291,183	462,423	478,821	481,135	482,677	483,449	484,991	490,390	494,246	498,103	499,274
-	Mohave County	-	22,171	36,827	44,837	48,520	50,976	52,203	54,658	63,252	69,390	75,528	77,392
-	Pima County	-	114,284	203,421	211,115	211,115	211,115	211,115	211,115	211,115	211,115	211,115	211,115
-	Pinal County	-	16,792	27,423	28,341	28,341	28,341	28,341	28,341	28,341	28,341	28,341	28,341
-	Yuma County	-	849	1,411	53,590	53,876	53,955	53,994	54,074	54,351	54,549	54,746	54,807
-	**Subtotal Arizona Domestic**	-	**450,311**	**740,138**	**831,365**	**841,529**	**848,194**	**851,527**	**858,192**	**881,520**	**898,182**	**914,845**	**919,905**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	0	0	219,986	375,955	388,002	388,002	388,002	388,002	388,002	388,002	388,002
-	Imperial County	-	0	0	0	0	0	0	0	0	0	0	11
-	Riverside County	-	0	0	0	0	0	0	0	0	0	0	1
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	196
-	**Subtotal California Domestic**	-	**0**	**0**	**219,986**	**375,955**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,002**	**388,210**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	42,097	70,162	105,243	126,292	140,324	147,341	161,373	210,486	245,568	280,649	291,602
-	**Subtotal Nevada Domestic**	-	**42,097**	**70,162**	**105,243**	**126,292**	**140,324**	**147,341**	**161,373**	**210,486**	**245,568**	**280,649**	**291,602**

[1]This user also holds a PPR entitlement.

Disclaimer: These modeling results for the Priority (w/o Tribal Shortage) Alternative Distribution Model should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

C.8 Pro Rata Alternative Distribution Model

The Pro Rata Alternative Distribution Model represents a distribution of shortages outside the priority system. It simulates shortages and distributes water on a proportional basis (i.e., at the same percentage reduction from each user's entitlement) across all lower Colorado River and CAP water users. This Alternative Distribution Model reflects a modeling commitment to stakeholders to display the results of this distribution of water; it is not an interpretation of law, contracts, or a legal position.

The Excel workbook contains formulas extending into deep shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.8.1 Distribution Among Water Users

In contrast to the Shortage Allocation Models, which distribute water among the Lower Division States according to a specified state-level distribution, the Pro Rata Alternative Distribution Model distributes water across all lower Colorado River and CAP water users based on their entitlement, without regard to state lines.

Entitlements, as modeled for the Priority Shortage Allocation Model, form the baseline against which shortages are assessed for each water user. Each entitlement's percentage share of the total shortage is calculated as the ratio of the entitlement to the sum of all entitlements, including 1.5 mafy for Mexico. The resulting percentages are multiplied by the volume of total shortage to determine the volume of shortage assigned to each entitlement. At a given level of shortage, as a consequence of how that shortage is distributed as described in this paragraph, all entitlements bear the same percentage reduction. The volume of shortage assigned to a water user with entitlements in different priority categories is the sum across multiple line items in the model; designations of priority do not affect the function of this Alternative Distribution Model but are retained to facilitate comparison of the results between models.

PPRs are not recognized in this Alternative Distribution Model as a basin-wide first priority without regard to state lines, and PPRs are included in the distribution of shortages.

In the Pro Rata Alternative Distribution Model, the internal CAP priority system set forth in the CAP Master Repayment Contract and elsewhere is assumed to be inoperable. Instead, individual long-term CAP contracts and subcontracts (rather than the Master CAP Repayment Contract) are modeled as mainstream consumptive use equivalents, with 5 percent for CAP main system loss added to the contract or subcontract volume; all other entitlements are shown as calculated for the Priority Shortage Allocation Model. As a result, this Alternative Distribution Model does not emulate an Arizona P4 shortage sharing formula and does not calculate an Available CAP Supply or a volume of shortage for CAP at the project level. Note that entitlements within the state of Arizona, as modeled in all models, exceed the state's 2.8 maf annual apportionment. In this Alternative Distribution Model, unlike in priority-based modeling, that causes the proportional

shortage to Arizona's apportionment to slightly exceed (within a single percentage point) the proportional shortage to the apportionments and allocation of California, Nevada, and Mexico, respectively, meaning the Lower Division States and Mexico bear shortage not precisely in proportion to their apportionments or allotment.

C.8.2 Pro Rata Alternative Distribution Model Results

The tables in this section present the results of the Pro Rata Alternative Distribution Model over a range of total shortages to the Lower Basin including Mexico.

Table C-38, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-39, the Tribal Summary, presents the shortage impacts on tribes.

Table C-40, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-41, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-38
Pro Rata Alternative Distribution Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
Arizona	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion[2]	-	-	-	-	-	-	-	-	-	-	-
-	NIA Priority	19,090	31,817	47,726	57,271	63,635	66,817	73,180	95,452	111,361	127,270	159,087
-	M&I Priority	44,604	74,340	111,510	133,812	148,680	156,114	170,982	223,020	260,190	297,360	371,701
-	Indian Priority	23,955	39,924	59,886	71,864	79,848	83,841	91,826	119,773	139,735	159,697	199,621
-	4th Priority i (Mainstream)	7,245	12,076	18,114	21,736	24,151	25,359	27,774	36,227	42,265	48,303	60,379
-	2nd & 3rd Priorities	53,069	88,448	132,672	159,206	176,896	185,741	203,430	265,344	309,568	353,792	442,240
-	1st Priority (Present Perfected Rights)	39,753	66,255	99,382	119,259	132,510	139,135	152,386	198,764	231,892	265,019	331,274
-	**Subtotal**	**187,716**	**312,860**	**469,290**	**563,149**	**625,721**	**657,007**	**719,579**	**938,581**	**1,095,011**	**1,251,441**	**1,564,302**
-	-	-	-	-	-	-	-	-	-	-	-	-
California	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	25,801	43,002	64,503	77,403	86,004	90,304	98,904	129,006	150,506	172,007	215,009
-	3rd Priority (IID, CVWD, PVID)	55,525	92,542	138,813	166,576	185,084	194,339	212,847	277,627	323,898	370,169	462,711
-	2nd Priority (Yuma Project Reservation Division)	485	808	1,213	1,455	1,617	1,698	1,859	2,425	2,829	3,234	4,042
-	1st Priority (PVID)	24,496	40,827	61,240	73,489	81,654	85,737	93,902	122,481	142,894	163,308	204,135
-	Present Perfected Rights (PPRs)	186,281	310,468	465,702	558,843	620,936	651,983	714,077	931,404	1,086,638	1,241,872	1,552,341
-	**Subtotal**	**292,589**	**487,648**	**731,471**	**877,766**	**975,295**	**1,024,060**	**1,121,589**	**1,462,943**	**1,706,766**	**1,950,590**	**2,438,238**
Nevada	**Priority**	**-**	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	6,165	10,276	15,414	18,496	20,551	21,579	23,634	30,827	35,965	41,103	51,378
-	8th Priority (SNWA & Big Bend)	10,838	18,063	27,094	32,513	36,126	37,932	41,545	54,189	63,220	72,252	90,315
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	150	250	375	450	500	525	575	750	876	1,001	1,251
-	6th Priority (Las Vegas Valley Water District)	533	888	1,332	1,598	1,776	1,865	2,042	2,664	3,108	3,552	4,440
-	5th Priority (PABCO)	32	53	80	96	107	112	123	160	187	214	267

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-	-	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	4th Priority (Henderson & Basic)	1,350	2,250	3,375	4,049	4,499	4,724	5,174	6,749	7,874	8,999	11,248
-	3rd Priority (Boulder City)	203	339	508	610	677	711	779	1,016	1,185	1,355	1,693
-	2nd Priority (Lake Mead National Rec Area)	100	166	249	299	332	349	382	499	582	665	831
-	1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	578	964	1,446	1,735	1,928	2,024	2,217	2,892	3,374	3,856	4,820
-	**Subtotal**	**19,949**	**33,249**	**49,873**	**59,848**	**66,497**	**69,822**	**76,472**	**99,746**	**116,370**	**132,995**	**166,243**
-	**Lower Division States Subtotal**	**500,254**	**833,757**	**1,250,635**	**1,500,762**	**1,667,513**	**1,750,889**	**1,917,640**	**2,501,270**	**2,918,148**	**3,335,026**	**4,168,783**
Mexico	**Mexico Subtotal**	**99,746**	**166,243**	**249,365**	**299,238**	**332,487**	**349,111**	**382,360**	**498,730**	**581,852**	**664,974**	**831,217**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here.

[2]The CAP priority system is not maintained in the pro rata distribution. CAP contractors and subcontractors are shorted pro rata with non-CAP water users; therefore, there is not an Available CAP Supply calculated for pro rata alternative distribution models, or a shortage volume given for CAP as a whole.

Disclaimer: These modeling results for the pro rata alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).

Table C-39
Pro Rata Alternative Distribution Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	1,661	2,768	4,151	4,982	5,535	5,812	6,365	8,303	9,686	11,070	13,838
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	1,969	3,282	4,922	5,907	6,563	6,891	7,548	9,845	11,486	13,127	16,408
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	8,421	14,034	21,051	25,262	28,069	29,472	32,279	42,103	49,120	56,137	70,171
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	279	465	698	838	931	978	1,071	1,396	1,629	1,862	2,327
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	13,350	22,250	33,375	40,050	44,500	46,725	51,175	66,750	77,875	89,000	111,250
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	2,639	4,399	6,598	7,918	8,798	9,237	10,117	13,196	15,396	17,595	21,994
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	85	142	213	255	283	298	326	425	496	567	709
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	4,071	6,784	10,177	12,212	13,569	14,247	15,604	20,353	23,745	27,138	33,922
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	1,273	2,122	3,183	3,819	4,244	4,456	4,880	6,365	7,426	8,487	10,609
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	35	58	87	105	116	122	134	175	204	233	291
CAP Indian Priority	San Carlos Apache Tribe	Gila County	887	1,478	2,217	2,660	2,956	3,104	3,399	4,434	5,173	5,912	7,390
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	929	1,548	2,322	2,786	3,095	3,250	3,560	4,643	5,417	6,191	7,739
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	559	931	1,396	1,676	1,862	1,955	2,141	2,793	3,258	3,724	4,655
CAP Indian Priority	Tonto Apache Tribe	Gila County	9	15	22	27	30	31	34	45	52	60	74
CAP Indian Priority	Yavapai Apache Nation	Gila County	84	140	209	251	279	293	321	419	489	559	698
CAP M&I Priority	San Carlos Apache Tribe	Gila County	1,267	2,112	3,167	3,801	4,223	4,434	4,857	6,335	7,390	8,446	10,558
4(i)	Hopi Tribe[1]	La Paz County	202	337	505	606	673	707	774	1,010	1,178	1,347	1,683
4(i)	Cocopah Indian Reservation	Yuma County	90	150	226	271	301	316	346	451	527	602	752

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	233	388	582	698	776	815	892	1,164	1,358	1,552	1,940
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	680	1,134	1,701	2,041	2,268	2,381	2,608	3,401	3,968	4,535	5,669
3	Ak-Chin Indian Community[1]	Pinal County	3,325	5,541	8,312	9,975	11,083	11,637	12,745	16,624	19,395	22,166	27,707
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	342	570	856	1,027	1,141	1,198	1,312	1,711	1,996	2,281	2,852
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	51	85	127	152	169	178	195	254	296	339	423
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	2,713	4,522	6,784	8,140	9,045	9,497	10,402	13,567	15,829	18,090	22,612
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	1,004	1,674	2,511	3,013	3,348	3,515	3,850	5,022	5,859	6,696	8,369
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	266	443	665	798	887	931	1,020	1,330	1,552	1,773	2,217
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	1,798	2,996	4,494	5,393	5,992	6,292	6,891	8,988	10,486	11,984	14,980
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	8,714	14,524	21,786	26,143	29,048	30,500	33,405	43,572	50,834	58,096	72,620
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	12,393	20,655	30,982	37,179	41,310	43,375	47,506	61,965	72,292	82,620	103,275
-	-	**Subtotal**	**69,328**	**115,546**	**173,320**	**207,983**	**231,093**	**242,647**	**265,757**	**346,639**	**404,412**	**462,185**	**577,732**
California			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	407	679	1,018	1,222	1,357	1,425	1,561	2,036	2,375	2,715	3,393
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	600	1,001	1,501	1,801	2,001	2,101	2,302	3,002	3,502	4,003	5,003
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	2,429	4,048	6,072	7,286	8,096	8,501	9,310	12,144	14,168	16,192	20,240
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	226	377	565	678	753	791	866	1,130	1,318	1,507	1,883
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	1,552	2,587	3,880	4,656	5,173	5,432	5,949	7,760	9,054	10,347	12,934
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	414	691	1,036	1,243	1,381	1,450	1,589	2,072	2,417	2,763	3,453
-	-	**Subtotal**	**5,629**	**9,381**	**14,072**	**16,886**	**18,763**	**19,701**	**21,577**	**28,144**	**32,835**	**37,525**	**46,907**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	558	931	1,396	1,675	1,861	1,955	2,141	2,792	3,258	3,723	4,654
-	-	**Subtotal**	**558**	**931**	**1,396**	**1,675**	**1,861**	**1,955**	**2,141**	**2,792**	**3,258**	**3,723**	**4,654**
-	-	**Total**	**75,515**	**125,858**	**188,788**	**226,545**	**251,717**	**264,303**	**289,474**	**377,575**	**440,505**	**503,434**	**629,292**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	217	362	543	652	724	760	833	1,086	1,267	1,448	1,810
-	Gila County	-	2,828	4,714	7,071	8,485	9,427	9,899	10,842	14,141	16,498	18,855	23,569
-	La Paz County	-	23,107	38,512	57,767	69,321	77,023	80,874	88,577	115,535	134,790	154,046	192,558
-	Maricopa County	-	8,733	14,555	21,832	26,199	29,110	30,565	33,476	43,664	50,942	58,219	72,774
-	Mohave County	-	3,857	6,429	9,644	11,572	12,858	13,501	14,787	19,287	22,502	25,716	32,145
-	Pima County	-	4,643	7,739	11,608	13,930	15,477	16,251	17,799	23,216	27,085	30,955	38,693
-	Pinal County	-	23,193	38,656	57,984	69,580	77,312	81,177	88,908	115,967	135,295	154,623	193,279
-	Yuma County	-	1,430	2,383	3,574	4,289	4,765	5,003	5,480	7,148	8,339	9,530	11,913
-	Apache County	-	659	1,099	1,649	1,978	2,198	2,308	2,528	3,297	3,847	4,396	5,495
-	Navajo County	-	659	1,099	1,649	1,978	2,198	2,308	2,528	3,297	3,847	4,396	5,495
-	**Subtotal Arizona Tribal**	-	**69,328**	**115,546**	**173,320**	**207,983**	**231,093**	**242,647**	**265,757**	**346,639**	**404,412**	**462,185**	**577,732**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	2104	3506	5260	6311	7013	7363	8065	10519	12272	14026	17532
-	Riverside	-	1096	1827	2741	3289	3654	3837	4202	5481	6395	7308	9135
-	Imperial	-	2429	4048	6072	7286	8096	8501	9310	12144	14168	16192	20240
-	**Subtotal California Tribal**	-	**5629**	**9381**	**14072**	**16886**	**18763**	**19701**	**21577**	**28144**	**32835**	**37525**	**46907**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	558	931	1396	1675	1861	1955	2141	2792	3258	3723	4654
-	**Subtotal Nevada Tribal**	-	**558**	**931**	**1396**	**1675**	**1861**	**1955**	**2141**	**2792**	**3258**	**3723**	**4654**

[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and Tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Disclaimer: These modeling results for the pro rata alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Table C-40
Pro Rata Alternative Distribution Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	136	226	340	408	453	476	521	679	793	906	1,132
4(i)	Arizona State Land Department	Yuma County	281	469	703	844	937	984	1,078	1,406	1,640	1,875	2,343
4(i)	Beattie Farms, Southwest	Yuma County	48	80	120	144	160	168	184	240	280	320	400
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	20	33	50	59	66	69	76	99	116	132	165
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	6	10	15	18	20	21	23	30	35	40	50
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	91	151	227	272	303	318	348	454	529	605	756
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	10	17	25	31	34	36	39	51	59	68	85
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	351	586	878	1,054	1,171	1,230	1,347	1,757	2,050	2,343	2,928
4(i)	Curtis, Armon	Yuma County	13	22	32	39	43	45	50	65	76	86	108
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	54	91	136	163	181	190	209	272	317	363	453
4(i)	Matador Farms, LLC	La Paz County	195	324	486	584	648	681	746	973	1,135	1,297	1,621
4(i)	JRJ Partners, L.L.C.	Yuma County	47	78	117	140	156	163	179	233	272	311	389
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	1,259	2,098	3,147	3,777	4,197	4,406	4,826	6,295	7,344	8,393	10,491
4(i)	North Baja Pipeline, LLC[2]	La Paz County	21	35	52	62	69	73	80	104	121	138	173
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	40	67	100	120	133	140	153	200	233	266	333
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	21	35	52	62	69	73	80	104	121	138	173
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	21	35	53	63	70	74	81	105	123	140	175
4(i)	Red River Land Company, LLC	La Paz County	14	24	35	42	47	50	54	71	83	94	118
4(i)	Phillips, Milton and Jean	Yuma County	4	7	10	12	13	14	15	20	23	27	33
4(i)	Western Water, LLC	La Paz County	26	43	64	77	86	90	98	128	150	171	214
3	Sturges, Harold	Yuma County	22	37	56	67	74	78	85	111	130	149	186
3	Sturges, Irma	Yuma County	26	43	64	77	85	90	98	128	149	171	213

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	9,411	15,684	23,527	28,232	31,369	32,937	36,074	47,053	54,895	62,738	78,422
3	Yuma Irrigation District (5 kaf M&I)[1]	Yuma County	4,474	7,456	11,185	13,421	14,913	15,658	17,150	22,369	26,097	29,825	37,282
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	448	746	1,119	1,343	1,492	1,567	1,716	2,238	2,611	2,984	3,730
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	18,486	30,810	46,216	55,459	61,621	64,702	70,864	92,431	107,837	123,242	154,052
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	238	397	596	715	794	834	913	1,191	1,390	1,588	1,985
3	Yuma County Water Users' Association (14,701 kaf M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	5,274	8,789	13,184	15,821	17,578	18,457	20,215	26,368	30,762	35,157	43,946
3	University of Arizona	Yuma County	72	121	181	217	241	253	277	362	422	483	603
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	8	13	20	24	27	28	31	40	47	53	66
3	Unit B Irrigation & Drainage District[3]	Yuma County	1,123	1,871	2,807	3,369	3,743	3,930	4,304	5,614	6,550	7,486	9,357
1	PPR No. 15, Molina	Yuma County	21	35	53	63	70	74	81	106	123	141	176
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	30	49	74	89	99	103	113	148	172	197	246
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	289	482	723	868	965	1,013	1,109	1,447	1,688	1,929	2,412
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	407	679	1,018	1,222	1,358	1,426	1,561	2,036	2,376	2,715	3,394
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	11,325	18,876	28,314	33,976	37,751	39,639	43,414	56,627	66,065	75,503	94,379
1	PPR No. 7, Powers	Yuma County	41	69	104	124	138	145	159	207	242	277	346
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	26	43	65	78	86	90	99	129	151	172	215
1	PPR No. 10, Hulet (MVIDD)	Mohave County	39	65	97	116	129	136	149	194	226	259	323
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	38	63	94	113	126	132	145	189	220	251	314
1	PPR No. 12, Miller (MVIDD)	Mohave County	9	14	22	26	29	30	33	43	50	57	72
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	29	48	73	87	97	102	111	145	170	194	242
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	39	65	97	116	129	136	149	194	226	259	323
1	PPR No. 18, Swan (MVIDD)	Mohave County	34	57	86	103	115	121	132	172	201	230	287

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	3	5	7	8	9	10	11	14	16	19	23
-	-	**Subtotal**	**54,569**	**90,948**	**136,421**	**163,706**	**181,895**	**190,990**	**209,179**	**272,843**	**318,316**	**363,790**	**454,738**
California			**-**	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	332	554	831	997	1,108	1,164	1,275	1,662	1,940	2,217	2,771
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	21,944	36,574	54,860	65,832	73,147	76,804	84,119	109,721	128,007	146,294	182,868
3	Imperial Irrigation District (IID) (3a)	Imperial County	33,249	55,414	83,122	99,746	110,829	116,370	127,453	166,243	193,951	221,658	277,072
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	485	808	1,213	1,455	1,617	1,698	1,859	2,425	2,829	3,234	4,042
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	24,496	40,827	61,240	73,489	81,654	85,737	93,902	122,481	142,894	163,308	204,135
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	8	13	19	23	26	27	29	38	45	51	64
PPR	PPR No. 41, Chagnon	San Bernardino	5	9	13	15	17	18	20	26	30	34	43
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	4	7	10	12	14	14	16	20	24	27	34
PPR	PPR No. 34, Milpitas	Imperial County	5	8	11	14	15	16	18	23	27	31	38
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	1,298	2,163	3,245	3,894	4,326	4,543	4,975	6,489	7,571	8,653	10,816
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	172,893	288,155	432,233	518,680	576,311	605,126	662,757	864,466	1,008,544	1,152,621	1,440,777
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	6,284	10,474	15,711	18,853	20,948	21,995	24,090	31,422	36,659	41,896	52,370
PPR	PPR No. 42, Lawrence	Imperial County	5	9	13	15	17	18	20	26	30	34	43
PPR	PPR No. 37, Milpitas	Imperial County	3	5	7	9	10	10	11	15	17	20	24
PPR	PPR No. 33, Morgan	Imperial County	6	11	16	19	21	22	24	32	37	43	53
PPR	PPR No. 35, Simons	San Bernardino	3	4	6	8	9	9	10	13	15	17	21
-	-	**Subtotal**	**261,020**	**435,034**	**652,551**	**783,061**	**870,068**	**913,571**	**1,000,578**	**1,305,102**	**1,522,619**	**1,740,136**	**2,175,170**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**315,589**	**525,982**	**788,972**	**946,767**	**1,051,963**	**1,104,561**	**1,209,758**	**1,577,945**	**1,840,935**	**2,103,926**	**2,629,908**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	778	1,297	1,946	2,335	2,594	2,724	2,984	3,892	4,540	5,189	6,486
-	Mohave County	-	1,472	2,454	3,681	4,417	4,908	5,153	5,644	7,361	8,588	9,815	12,269
-	Yuma County	-	52,318	87,197	130,795	156,954	174,393	183,113	200,552	261,590	305,188	348,786	435,983
-	**Subtotal Arizona Irrigation**	-	**54,569**	**90,948**	**136,421**	**163,706**	**181,895**	**190,990**	**209,179**	**272,843**	**318,316**	**363,790**	**454,738**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	37,667	62,778	94,167	113,001	125,556	131,834	144,390	188,334	219,724	251,113	313,891
-	Imperial County	-	223,342	372,236	558,354	670,025	744,473	781,696	856,143	1,116,709	1,302,827	1,488,945	1,861,181
-	San Bernardino	-	12	20	29	35	39	41	45	59	69	78	98
-	**Subtotal California Irrigation**	-	**261,020**	**435,034**	**652,551**	**783,061**	**870,068**	**913,571**	**1,000,578**	**1,305,102**	**1,522,619**	**1,740,136**	**2,175,170**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.

[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.

[3]This user also holds a PPR entitlement.

Disclaimer: These modeling results for the pro rata alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

Table C-41
Pro Rata Alternative Distribution Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	195	324	486	584	648	681	746	973	1,135	1,297	1,621
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	1,270	2,116	3,174	3,809	4,232	4,444	4,867	6,349	7,407	8,465	10,581
CAP NIA-B	Carefree Water Company	Maricopa County	8	13	20	23	26	27	30	39	46	52	65
CAP NIA-B	Cave Creek	Maricopa County	27	45	67	81	90	94	103	135	157	180	225
CAP NIA-B	El Mirage	Maricopa County	92	153	230	276	307	322	353	460	537	614	767
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	225	374	562	674	749	786	861	1,123	1,310	1,497	1,872
CAP NIA-B	Freeport	Pima County	396	661	991	1,189	1,322	1,388	1,520	1,982	2,313	2,643	3,304
CAP NIA-B	Gilbert	Maricopa County	128	213	320	384	426	448	490	640	746	853	1,066
CAP NIA-B	Marana	Pima County	36	60	90	108	120	126	138	180	210	240	300
CAP NIA-B	Queen Creek	Maricopa County	291	484	727	872	969	1,017	1,114	1,453	1,695	1,937	2,422
CAP NIA-B	Resolution Copper	Maricopa County	156	260	391	469	521	547	599	781	912	1,042	1,302
CAP NIA-B	Rosemont Copper	Pima County	78	131	196	235	262	275	301	392	458	523	654
CAP NIA-B	SRP	Maricopa County	151	251	377	452	503	528	578	754	880	1,005	1,257
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	57	95	143	171	190	200	219	285	333	380	475
CAP NIA-A	Phoenix	Maricopa County	2,603	4,338	6,507	7,809	8,677	9,110	9,978	13,015	15,184	17,353	21,691
CAP NIA-A	Chandler	Maricopa County	274	457	685	822	913	959	1,050	1,370	1,598	1,827	2,283
CAP NIA-A	Gilbert	Maricopa County	107	179	268	322	358	376	411	537	626	715	894
CAP NIA-A	Glendale	Maricopa County	48	79	119	143	159	167	183	238	278	317	397
CAP NIA-A	Mesa	Maricopa County	388	646	969	1,163	1,292	1,357	1,486	1,938	2,261	2,584	3,230

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Scottsdale	Maricopa County	231	385	577	692	769	808	885	1,154	1,347	1,539	1,924
CAP NIA-A	Tempe	Maricopa County	2	3	4	5	5	6	6	8	9	11	13
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	35	58	87	105	116	122	134	175	204	233	291
CAP M&I	ASARCO	Pima County	1,466	2,444	3,666	4,399	4,888	5,132	5,621	7,331	8,553	9,775	12,219
CAP M&I	Avondale	Maricopa County	378	630	945	1,134	1,261	1,324	1,450	1,891	2,206	2,521	3,151
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	1,967	3,279	4,918	5,902	6,558	6,886	7,541	9,837	11,476	13,115	16,394
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	620	1,034	1,551	1,861	2,068	2,171	2,378	3,102	3,618	4,135	5,169
CAP M&I	Arizona Water Company, Coolidge	Pinal County	140	233	349	419	465	489	535	698	815	931	1,164
CAP M&I	Arizona Water Company, Superstition	Pinal County	439	731	1,097	1,316	1,463	1,536	1,682	2,194	2,560	2,926	3,657
CAP M&I	Arizona Water Company, White Tank	Maricopa County	68	113	169	203	225	237	259	338	394	451	563
CAP M&I	Buckeye	Maricopa County	5	8	12	14	16	17	18	24	28	32	40
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	449	748	1,122	1,346	1,496	1,570	1,720	2,243	2,617	2,991	3,739
CAP M&I	Carefree Water Company	Maricopa County	117	195	293	351	391	410	449	586	683	781	976
CAP M&I	Cave Creek	Maricopa County	156	259	389	467	519	544	596	778	907	1,037	1,296
CAP M&I	Chandler	Maricopa County	604	1,007	1,511	1,813	2,014	2,115	2,316	3,021	3,525	4,028	5,035
CAP M&I	Chaparral City Water Company	Maricopa County	622	1,037	1,555	1,866	2,073	2,177	2,385	3,110	3,629	4,147	5,184
CAP M&I	Circle City	Maricopa County	275	458	686	824	915	961	1,052	1,373	1,601	1,830	2,288
CAP M&I	El Mirage	Maricopa County	35	59	89	106	118	124	136	177	207	236	296
CAP M&I	Eloy	Pinal County	152	253	379	455	505	531	581	758	884	1,011	1,263
CAP M&I	EPCOR, Agua Fria	Maricopa County	775	1,291	1,936	2,324	2,582	2,711	2,969	3,873	4,518	5,164	6,454
CAP M&I	EPCOR, Paradise Valley	Maricopa County	226	376	564	677	752	790	865	1,128	1,316	1,504	1,880
CAP M&I	EPCOR, Sun City	Maricopa County	292	487	731	877	975	1,024	1,121	1,462	1,706	1,950	2,437

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	EPCOR, Sun City West	Maricopa County	166	276	414	497	552	580	635	828	966	1,104	1,380
CAP M&I	Florence	Pinal County	143	238	357	429	477	500	548	715	834	953	1,192
CAP M&I	Freeport-Miami	Gila County	203	338	507	609	676	710	778	1,015	1,184	1,353	1,691
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	199	332	498	598	664	697	764	996	1,162	1,328	1,661
CAP M&I	Gilbert	Maricopa County	505	842	1,263	1,515	1,684	1,768	1,936	2,526	2,947	3,368	4,210
CAP M&I	Glendale	Maricopa County	1,203	2,006	3,009	3,610	4,012	4,212	4,613	6,017	7,020	8,023	10,029
CAP M&I	Goodyear	Maricopa County	750	1,250	1,875	2,250	2,500	2,625	2,875	3,750	4,375	5,000	6,250
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	4	7	11	13	15	16	17	22	26	30	37
CAP M&I	Green Valley Community Water Company	Pima County	200	333	499	599	665	698	765	998	1,164	1,330	1,663
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	133	221	332	398	442	464	509	663	774	884	1,106
CAP M&I	Marana	Pima County	163	272	408	489	544	571	625	816	951	1,087	1,359
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	46	77	116	139	155	163	178	232	271	310	387
CAP M&I	Mesa	Maricopa County	3,037	5,062	7,594	9,112	10,125	10,631	11,644	15,187	17,719	20,250	25,312
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	940	1,566	2,350	2,819	3,133	3,289	3,603	4,699	5,482	6,265	7,832
CAP M&I	Oro Valley	Pima County	720	1,199	1,799	2,159	2,398	2,518	2,758	3,598	4,197	4,797	5,996
CAP M&I	Peoria	Maricopa County	1,894	3,156	4,734	5,681	6,312	6,628	7,259	9,468	11,046	12,624	15,780
CAP M&I	Phoenix	Maricopa County	8,805	14,675	22,012	26,415	29,350	30,817	33,752	44,024	51,362	58,699	73,374
CAP M&I	Pine	Gila County	11	19	28	34	37	39	43	56	66	75	94
CAP M&I	Queen Creek	Maricopa County	35	58	86	104	115	121	132	173	202	230	288
CAP M&I	Rio Verde Utilities	Maricopa County	57	94	142	170	189	198	217	283	331	378	472
CAP M&I	San Tan Irrigation District	Maricopa County	16	27	41	49	55	58	63	82	96	110	137
CAP M&I	Scottsdale	Maricopa County	3,687	6,146	9,218	11,062	12,291	12,906	14,135	18,437	21,509	24,582	30,728
CAP M&I	Spanish Trail Water Company	Pima County	212	353	530	636	707	742	813	1,060	1,237	1,414	1,767

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Surprise	Maricopa County	716	1,193	1,789	2,147	2,385	2,505	2,743	3,578	4,174	4,771	5,963
CAP M&I	Tempe	Maricopa County	301	502	753	904	1,004	1,054	1,155	1,506	1,757	2,009	2,511
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	5	8	12	15	17	17	19	25	29	33	41
CAP M&I	Tucson	Pima County	10,068	16,780	25,169	30,203	33,559	35,237	38,593	50,339	58,728	67,118	83,898
CAP M&I	Vail Water Company	Pima County	130	216	324	389	432	454	497	648	756	864	1,080
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	204	340	510	611	679	713	781	1,019	1,189	1,359	1,698
4(i)	Arizona State Land Department	Yuma County	65	109	163	196	218	228	250	326	381	435	544
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	4	6	10	12	13	14	15	19	23	26	32
4(i)	B&F Investment, LLC	La Paz County	3	5	7	8	9	10	11	14	16	18	23
4(i)	Bullhead City	Mohave County	668	1,113	1,669	2,003	2,225	2,336	2,559	3,338	3,894	4,450	5,563
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	94	156	235	282	313	329	360	469	548	626	782
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	307	512	768	922	1,024	1,075	1,178	1,536	1,792	2,048	2,560
4(i)	Bureau of Land Management	La Paz County	267	444	667	800	889	933	1,022	1,333	1,555	1,778	2,222
4(i)	Crystal Beach Water Conservation District	Mohave County	6	10	14	17	19	20	22	29	33	38	48
4(i)	Ehrenburg Improvement District	La Paz County	31	51	77	92	103	108	118	154	180	205	257
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	82	137	206	247	274	288	315	411	480	548	685
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	2	4	6	7	8	8	9	12	14	16	20
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	0	0	0	0	0	0	1
4(i)	Gold Dome Mining Corporation	Yuma County	0	1	1	1	2	2	2	2	3	3	4
4(i)	Golden Shores Water Conservation District	Mohave County	89	149	223	267	297	312	342	446	520	594	743
4(i)	GSC Farm, LLC	La Paz County	3	6	8	10	11	12	13	17	20	22	28
4(i)	Hillcrest Water Company	La Paz County	4	6	9	11	12	13	14	18	21	24	30

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Lake Havasu City	Mohave County	791	1,319	1,978	2,374	2,638	2,769	3,033	3,956	4,616	5,275	6,594
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	88	147	220	265	294	309	338	441	514	588	735
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	299	498	747	897	996	1,046	1,146	1,495	1,744	1,993	2,491
4(i)	La Paz County	La Paz County	23	39	58	70	78	81	89	116	136	155	194
4(i)	Martinez Lake Cabin Sites	Yuma County	1	2	2	3	3	3	4	5	6	7	8
4(i)	McAlister Family Trust	Mohave County	2	3	5	6	6	6	7	9	11	12	15
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	45	75	112	135	150	157	172	224	262	299	374
4(i)	Mohave Water Conservation District	Mohave County	80	134	200	241	267	281	307	401	468	535	668
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	134	223	334	401	446	468	512	668	780	891	1,114
4(i)	Parker, Town of[1]	La Paz County	29	48	72	86	96	101	110	144	168	192	240
4(i)	Quartzsite, Town of	La Paz County	71	119	178	213	237	249	273	356	415	474	593
4(i)	Queen Creek, Town of	Maricopa County	135	225	338	406	451	473	518	676	789	901	1,127
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	0	0	0	0	0	0	1
4(i)	Shepard Water Company, Incorporated	Yuma County	2	4	5	6	7	8	8	11	13	14	18
4(i)	Somerton, City of	Yuma County	50	83	125	150	166	175	191	249	291	332	416
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	5	8	12	15	16	17	19	24	28	32	40
4(i)	TV Marble Canyon AZ, LLC	Coconino County	3	5	8	9	10	11	12	15	18	20	25
3	City of Yuma[1]	Yuma County	3,227	5,378	8,066	9,680	10,755	11,293	12,369	16,133	18,822	21,511	26,888
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	2	3	4	5	6	6	6	8	10	11	14
3	Kaman, Inc.	Yuma County	0	0	0	0	0	0	1	1	1	1	1
3	Department of the Navy, MCAS	Yuma County	199	332	499	598	665	698	765	997	1,164	1,330	1,662
3	City of Yuma (cemetery)	Yuma County	4	7	10	12	13	14	15	20	23	27	33

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Mesa Fruit Growers' Association	Yuma County	1	2	2	3	3	3	4	5	6	7	8
3	Desert Lawn Memorial Park Association	Yuma County	9	15	23	28	31	32	35	46	54	61	76
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	284	474	711	853	948	996	1,090	1,422	1,659	1,897	2,371
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	450	749	1,124	1,349	1,499	1,574	1,724	2,248	2,623	2,998	3,747
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	199	332	499	598	665	698	765	997	1,164	1,330	1,662
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	184	306	459	551	612	642	704	918	1,071	1,224	1,529
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	332	554	831	997	1,108	1,164	1,275	1,662	1,940	2,217	2,771
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	7	11	17	20	22	23	25	33	39	44	55
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	7	11	17	20	22	23	25	33	39	44	55
3	Department of the Army - Yuma Proving Ground	Yuma County	75	125	188	225	250	263	288	375	438	501	626
3	Yuma Union High School District	Yuma County	10	16	25	30	33	34	38	49	57	66	82
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	17	28	41	50	55	58	63	83	96	110	138
2	Cibola National Wildlife Refuge	La Paz County	1,117	1,861	2,792	3,350	3,722	3,908	4,281	5,583	6,514	7,445	9,306
2	Lake Mead National Recreation Area	Mohave County	23	38	57	68	76	80	87	114	133	152	190
2	Bureau of Reclamation - Davis Dam	Mohave County	0	1	1	1	2	2	2	2	3	3	4
2	Imperial National Wildlife Refuge	La Paz County	1,529	2,549	3,824	4,588	5,098	5,353	5,863	7,647	8,922	10,196	12,745
2	Havasu Lake National Wildlife Refuge	Mohave County	2,487	4,145	6,217	7,461	8,290	8,704	9,533	12,435	14,507	16,580	20,724
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	16	26	39	47	53	55	61	79	92	105	132
1	PPR No. 20, Parker, City of	La Paz County	27	44	66	80	89	93	102	133	155	177	222
1	PPR No. 21, Yuma, City of	Yuma County	98	164	246	295	328	344	377	491	573	655	819
-	-	**Subtotal**	**63,820**	**106,366**	**159,550**	**191,460**	**212,733**	**223,369**	**244,643**	**319,099**	**372,282**	**425,466**	**531,832**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	25,801	43,002	64,503	77,403	86,004	90,304	98,904	129,006	150,506	172,007	215,009
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 30, Stephenson	San Bernardino	10	17	26	31	34	36	39	51	60	68	85
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 38, Andrade	San Bernardino	3	5	7	8	9	10	11	14	16	19	23
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	3	4	6	8	9	9	10	13	15	17	21
PPR	PPR No. 39, Reynolds	San Bernardino	2	3	4	5	5	5	6	8	9	10	13
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	18	30	45	54	61	64	70	91	106	121	151
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	5	9	13	15	17	18	20	26	30	34	43
PPR	PPR No. 43, City of Needles	San Bernardino	63	105	158	190	211	221	242	316	369	421	526
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	33	55	83	100	111	116	127	166	194	221	277
-	-	**Subtotal**	**25,939**	**43,232**	**64,848**	**77,818**	**86,464**	**90,787**	**99,434**	**129,696**	**151,312**	**172,929**	**216,161**
Nevada			**-**	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	**-**	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	6,165	10,276	15,414	18,496	20,551	21,579	23,634	30,827	35,965	41,103	51,378
8	Big Bend Water District	Clark	326	543	815	978	1,086	1,140	1,249	1,629	1,901	2,172	2,715
8	Robert B. Griffith Project	Clark	10,512	17,520	26,280	31,536	35,040	36,792	40,296	52,560	61,319	70,079	87,599
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	1	1	1	1	1	1	2	2	2	3
7	Bureau of Reclamation (includes Sportsman Park)	Clark	10	16	24	29	33	34	37	49	57	65	81
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	2	3	4	5	6	6	6	8	10	11	14
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	138	231	346	415	461	484	530	692	807	922	1,153
6	Las Vegas Valley Water District	Clark	533	888	1,332	1,598	1,776	1,865	2,042	2,664	3,108	3,552	4,440
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	32	53	80	96	107	112	123	160	187	214	267
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	284	473	710	851	946	993	1,088	1,419	1,656	1,892	2,365
4	City of Henderson	Clark	549	915	1,373	1,647	1,830	1,922	2,105	2,745	3,203	3,660	4,575
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	517	862	1,292	1,551	1,723	1,809	1,982	2,585	3,016	3,446	4,308

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Boulder City	Clark	203	339	508	610	677	711	779	1,016	1,185	1,355	1,693
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	100	166	249	299	332	349	382	499	582	665	831
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	20	33	50	60	66	70	76	100	116	133	166
-	-	**Subtotal**	**19,391**	**32,318**	**48,477**	**58,172**	**64,636**	**67,868**	**74,331**	**96,954**	**113,113**	**129,272**	**161,590**
-	-	**Total**	**109,150**	**181,917**	**272,875**	**327,450**	**363,833**	**382,025**	**418,408**	**545,750**	**636,708**	**727,666**	**909,583**
	Summary by County												
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	3	5	8	9	10	11	12	15	18	20	25
-	Gila County	-	214	357	535	642	714	750	821	1,071	1,249	1,428	1,785
-	La Paz County	-	3,124	5,206	7,810	9,371	10,413	10,933	11,975	15,619	18,222	20,825	26,032
-	Maricopa County	-	34,798	57,996	86,994	104,393	115,993	121,792	133,391	173,989	202,987	231,985	289,981
-	Mohave County	-	5,199	8,665	12,997	15,596	17,329	18,196	19,929	25,994	30,326	34,658	43,323
-	Pima County	-	14,741	24,568	36,851	44,222	49,135	51,592	56,505	73,703	85,986	98,270	122,838
-	Pinal County	-	1,979	3,298	4,947	5,936	6,596	6,926	7,586	9,894	11,543	13,192	16,490
-	Yuma County	-	3,763	6,272	9,407	11,289	12,543	13,170	14,425	18,815	21,951	25,087	31,358
-	**Subtotal Arizona Domestic**	-	**63,820**	**106,366**	**159,550**	**191,460**	**212,733**	**223,369**	**244,643**	**319,099**	**372,282**	**425,466**	**531,832**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	25,801	43,002	64,503	77,403	86,004	90,304	98,904	129,006	150,506	172,007	215,009
-	Imperial County	-	39	66	99	118	132	138	151	197	230	263	329
-	Riverside County	-	0	0	0	1	1	1	1	1	1	1	2
-	San Bernardino	-	98	164	246	295	328	345	377	492	574	656	821
-	**Subtotal California Domestic**	-	**25,939**	**43,232**	**64,848**	**77,818**	**86,464**	**90,787**	**99,434**	**129,696**	**151,312**	**172,929**	**216,161**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	19,391	32,318	48,477	58,172	64,636	67,868	74,331	96,954	113,113	129,272	161,590
-	**Subtotal Nevada Domestic**	-	**19,391**	**32,318**	**48,477**	**58,172**	**64,636**	**67,868**	**74,331**	**96,954**	**113,113**	**129,272**	**161,590**

[1]This user also holds a PPR entitlement.

[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Disclaimer: These modeling results for the pro rata alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.

C.9 Lower Basin Pro Rata Alternative Distribution Model

The Lower Basin Pro Rata Alternative Distribution Model represents a distribution of shortages outside the priority system. It simulates shortages and distributes water pro rata, without regard to priority, but within the framework of the Lower Division States proposal submitted on March 6, 2024. This Alternative Distribution Model reflects a modeling commitment to stakeholders to display the results of this distribution of water; it is not an interpretation of law, contracts, or a legal position.

The Excel workbook contains formulas to extend the proposed distribution to deeper shortage levels (pro rata) as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.9.1 Distribution Among States for the Lower Basin Pro Rata Alternative Distribution Model

The Lower Basin Pro Rata Alternative Distribution Model distributes shortages up to 1.5 maf among states based on the specified state reductions modeled and described for the Lower Basin Priority Shortage Allocation Model. Shortages in excess of 1.5 maf are distributed among the Lower Division States and Mexico in proportion to the unreduced remainder of each apportionment, as described below.

- Arizona bears 27.20 percent of the shortage in excess of 1.5 maf, computed as a ratio of Arizona's apportionment less the amount of shortage applied to Arizona under the Static Reduction Zone, over the sum of the apportionments of the Lower Division States and Mexico less the total amount of shortage applied to users under the Static Reduction Zone, or
    - (2.8 maf – 760 kaf) / (9.0 maf – 1.5 maf) = 27.20 percent
- California bears 52.80 percent of the shortage in excess of 1.5 maf, computed as a ratio of California's apportionment less the amount of shortage applied to California under the Static Reduction Zone, over the sum of the apportionments of the Lower Division States and Mexico less the total amount of shortage applied to users under the Static Reduction Zone, or
    - (4.4 maf – 440 kaf) / (9.0 maf – 1.5 maf) = 52.80 percent
- Nevada bears 3.33 percent of the shortage in excess of 1.5 maf, computed as a ratio of Nevada's apportionment less the amount of shortage applied to Nevada under the Static

Reduction Zone, over the sum of the apportionments of the Lower Division States and Mexico less the total amount of shortage applied to users under the Static Reduction Zone, or

  - (300 kaf – 50 kaf) / (9.0 maf – 1.5 maf) = 3.33 percent

- Mexico bears 16.67 percent of the shortage in excess of 1.5 maf, computed as a ratio of Mexico's allotment less the amount of shortage applied to Mexico under the Static Reduction Zone, over the sum of the apportionments of the Lower Division States and Mexico less the total amount of shortage applied to users under the Static Reduction Zone, or

  - (1.5 maf – 250 kaf) / (9.0 maf – 1.5 maf) = 16.67 percent

PPRs are not recognized as a basin-wide first priority without regard to state lines and do not affect the distribution of shortage among states in this Alternative Distribution Model.

Table C-42 below shows a distribution of shortage among the Lower Division States and corresponding volumes of water available to each Lower Division State under the Lower Basin Pro Rata Shortage Allocation Model. Total shortage volumes include an assumed component for Mexico, as described in the sections that follow, and will not sum across rows.

Table C-42
Summary of Shortage Volumes and Available Water by Lower Division State Under the Lower Basin Pro Rata Alternative Distribution Model (af)

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
0	0	2,800,000	0	4,400,000	0	300,000
(100,000)	80,000	2,720,000	0	4,400,000	3,333	296,667
(200,000)	160,000	2,640,000	0	4,400,000	6,667	293,333
(300,000)	240,000	2,560,000	0	4,400,000	10,000	290,000
(400,000)	283,333	2,516,667	36,667	4,363,333	13,333	286,667
(500,000)	326,667	2,473,333	73,333	4,326,667	16,667	283,333
(600,000)	370,000	2,430,000	110,000	4,290,000	20,000	280,000
(700,000)	413,333	2,386,667	146,667	4,253,333	23,333	276,667
(800,000)	456,667	2,343,333	183,333	4,216,667	26,667	273,333
(900,000)	500,000	2,300,000	220,000	4,180,000	30,000	270,000
(1,000,000)	543,333	2,256,667	256,667	4,143,333	33,333	266,667
(1,100,000)	586,667	2,213,333	293,333	4,106,667	36,667	263,333
(1,200,000)	630,000	2,170,000	330,000	4,070,000	40,000	260,000
(1,300,000)	673,333	2,126,667	366,667	4,033,333	43,333	256,667
(1,400,000)	716,667	2,083,333	403,333	3,996,667	46,667	253,333
(1,500,000)	760,000	2,040,000	440,000	3,960,000	50,000	250,000

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(1,600,000)	787,200	2,012,800	492,800	3,907,200	53,333	246,667
(1,700,000)	814,400	1,985,600	545,600	3,854,400	56,667	243,333
(1,800,000)	841,600	1,958,400	598,400	3,801,600	60,000	240,000
(1,900,000)	868,800	1,931,200	651,200	3,748,800	63,333	236,667
(2,000,000)	896,000	1,904,000	704,000	3,696,000	66,667	233,333
(2,100,000)	923,200	1,876,800	756,800	3,643,200	70,000	230,000
(2,200,000)	950,400	1,849,600	809,600	3,590,400	73,333	226,667
(2,300,000)	977,600	1,822,400	862,400	3,537,600	76,667	223,333
(2,400,000)	1,004,800	1,795,200	915,200	3,484,800	80,000	220,000
(2,500,000)	1,032,000	1,768,000	968,000	3,432,000	83,333	216,667
(2,600,000)	1,059,200	1,740,800	1,020,800	3,379,200	86,667	213,333
(2,700,000)	1,086,400	1,713,600	1,073,600	3,326,400	90,000	210,000
(2,800,000)	1,113,600	1,686,400	1,126,400	3,273,600	93,333	206,667
(2,900,000)	1,140,800	1,659,200	1,179,200	3,220,800	96,667	203,333
(3,000,000)	1,168,000	1,632,000	1,232,000	3,168,000	100,000	200,000
(3,100,000)	1,195,200	1,604,800	1,284,800	3,115,200	103,333	196,667
(3,200,000)	1,222,400	1,577,600	1,337,600	3,062,400	106,667	193,333
(3,300,000)	1,249,600	1,550,400	1,390,400	3,009,600	110,000	190,000
(3,400,000)	1,276,800	1,523,200	1,443,200	2,956,800	113,333	186,667
(3,500,000)	1,304,000	1,496,000	1,496,000	2,904,000	116,667	183,333
(3,600,000)	1,331,200	1,468,800	1,548,800	2,851,200	120,000	180,000
(3,700,000)	1,358,400	1,441,600	1,601,600	2,798,400	123,333	176,667
(3,800,000)	1,385,600	1,414,400	1,654,400	2,745,600	126,667	173,333
(3,900,000)	1,412,800	1,387,200	1,707,200	2,692,800	130,000	170,000
(4,000,000)	1,440,000	1,360,000	1,760,000	2,640,000	133,333	166,667
(4,100,000)	1,467,200	1,332,800	1,812,800	2,587,200	136,667	163,333
(4,200,000)	1,494,400	1,305,600	1,865,600	2,534,400	140,000	160,000
(4,300,000)	1,521,600	1,278,400	1,918,400	2,481,600	143,333	156,667
(4,400,000)	1,548,800	1,251,200	1,971,200	2,428,800	146,667	153,333
(4,500,000)	1,576,000	1,224,000	2,024,000	2,376,000	150,000	150,000
(4,600,000)	1,603,200	1,196,800	2,076,800	2,323,200	153,333	146,667
(4,700,000)	1,630,400	1,169,600	2,129,600	2,270,400	156,667	143,333
(4,800,000)	1,657,600	1,142,400	2,182,400	2,217,600	160,000	140,000
(4,900,000)	1,684,800	1,115,200	2,235,200	2,164,800	163,333	136,667
(5,000,000)	1,712,000	1,088,000	2,288,000	2,112,000	166,667	133,333
(5,100,000)	1,739,200	1,060,800	2,340,800	2,059,200	170,000	130,000
(5,200,000)	1,766,400	1,033,600	2,393,600	2,006,400	173,333	126,667
(5,300,000)	1,793,600	1,006,400	2,446,400	1,953,600	176,667	123,333
(5,400,000)	1,820,800	979,200	2,499,200	1,900,800	180,000	120,000

Total Lower Basin Shortage Volumes	Arizona Shortage Volume	Arizona Available Water	California Shortage Volume	California Available Water	Nevada Shortage Volume	Nevada Available Water
(5,500,000)	1,848,000	952,000	2,552,000	1,848,000	183,333	116,667
(5,600,000)	1,875,200	924,800	2,604,800	1,795,200	186,667	113,333
(5,700,000)	1,902,400	897,600	2,657,600	1,742,400	190,000	110,000
(5,800,000)	1,929,600	870,400	2,710,400	1,689,600	193,333	106,667
(5,900,000)	1,956,800	843,200	2,763,200	1,636,800	196,667	103,333
(6,000,000)	1,984,000	816,000	2,816,000	1,584,000	200,000	100,000
(6,100,000)	2,011,200	788,800	2,868,800	1,531,200	203,333	96,667
(6,200,000)	2,038,400	761,600	2,921,600	1,478,400	206,667	93,333
(6,300,000)	2,065,600	734,400	2,974,400	1,425,600	210,000	90,000
(6,400,000)	2,092,800	707,200	3,027,200	1,372,800	213,333	86,667
(6,500,000)	2,120,000	680,000	3,080,000	1,320,000	216,667	83,333
(6,600,000)	2,147,200	652,800	3,132,800	1,267,200	220,000	80,000
(6,700,000)	2,174,400	625,600	3,185,600	1,214,400	223,333	76,667
(6,800,000)	2,201,600	598,400	3,238,400	1,161,600	226,667	73,333
(6,900,000)	2,228,800	571,200	3,291,200	1,108,800	230,000	70,000
(7,000,000)	2,256,000	544,000	3,344,000	1,056,000	233,333	66,667
(7,100,000)	2,283,200	516,800	3,396,800	1,003,200	236,667	63,333
(7,200,000)	2,310,400	489,600	3,449,600	950,400	240,000	60,000
(7,300,000)	2,337,600	462,400	3,502,400	897,600	243,333	56,667
(7,400,000)	2,364,800	435,200	3,555,200	844,800	246,667	53,333
(7,500,000)	2,392,000	408,000	3,608,000	792,000	250,000	50,000
(7,600,000)	2,419,200	380,800	3,660,800	739,200	253,333	46,667
(7,700,000)	2,446,400	353,600	3,713,600	686,400	256,667	43,333
(7,800,000)	2,473,600	326,400	3,766,400	633,600	260,000	40,000
(7,900,000)	2,500,800	299,200	3,819,200	580,800	263,333	36,667
(8,000,000)	2,528,000	272,000	3,872,000	528,000	266,667	33,333
(8,100,000)	2,555,200	244,800	3,924,800	475,200	270,000	30,000
(8,200,000)	2,582,400	217,600	3,977,600	422,400	273,333	26,667
(8,300,000)	2,609,600	190,400	4,030,400	369,600	276,667	23,333
(8,400,000)	2,636,800	163,200	4,083,200	316,800	280,000	20,000
(8,500,000)	2,664,000	136,000	4,136,000	264,000	283,333	16,667
(8,600,000)	2,691,200	108,800	4,188,800	211,200	286,667	13,333
(8,700,000)	2,718,400	81,600	4,241,600	158,400	290,000	10,000
(8,800,000)	2,745,600	54,400	4,294,400	105,600	293,333	6,667
(8,900,000)	2,772,800	27,200	4,347,200	52,800	296,667	3,333
(9,000,000)	2,800,000	0	4,400,000	0	300,000	0

C.9.2 Distribution Within States for the Lower Basin Pro Rata Alternative Distribution Model

The Lower Basin Pro Rata Alternative Distribution Model simulates shortages and distributes water on a proportional basis (i.e., at the same percentage reduction from each user's entitlement) within each of the Lower Division States according to the shortage calculated for the state as described in the previous section.

Entitlements, as modeled for the Priority Shortage Allocation Model, form the baseline against which shortages are assessed for each water user. Each entitlement's percentage share of the shortage to each state is calculated as the ratio of the entitlement to the sum of all entitlements within the state. The resulting percentages are multiplied by the volume of shortage to the state to determine the volume of shortage assigned to each entitlement. At a given level of shortage, as a consequence of how that shortage is distributed as described in this paragraph and the previous section, all entitlements within a given state bear the same percentage reduction, but bear a different percentage reduction from entitlements in a different state. The volume of shortage assigned to a water user with entitlements in different priority categories is the sum across multiple line items in the model; designations of priority do not affect the function of this Alternative Distribution Model, but are retained to facilitate comparison of the results between models.

Because PPRs are not recognized in this Alternative Distribution Model as a basin-wide first priority, PPRs are included in the distribution of shortages.

In the Lower Basin Pro Rata Alternative Distribution Model, as in the Pro Rata Alternative Distribution Model, the internal CAP priority system set forth in the CAP Master Repayment Contract and elsewhere is assumed to be inoperable. Instead, individual long-term CAP contracts and subcontracts (rather than the Master CAP Repayment Contract) are modeled as mainstream consumptive use equivalents, with 5 percent for CAP main system loss added to the contract or subcontract volume; all other entitlements are shown as calculated for the Priority Shortage Allocation Model. As a result, this Alternative Distribution Model does not emulate an Arizona P4 shortage sharing formula and does not calculate an Available CAP Supply or a volume of shortage for CAP at the project level. Note that entitlements within the state of Arizona, as modeled in all models, exceed the state's 2.8 maf annual apportionment; in this Alternative Distribution Model, unlike in priority-based modeling, that has a small effect on the distribution of water.

C.9.3 Lower Basin Pro Rata Alternative Distribution Model Results

The tables in this section present the results of the Lower Basin Pro Rata Alternative Distribution Model over a range of total shortages to the Lower Basin including Mexico.

Table C-43, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-44, the Tribal Summary, presents the shortage impacts on tribes.

Table C-45, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-46, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-43
Lower Basin Pro Rata Alternative Distribution Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-	-	600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion	-	-	-	-	-	-	-	-	-	-	-
-	NIA Priority	37,628	55,256	77,291	85,589	91,122	93,888	99,420	118,784	132,615	146,446	174,108
-	M&I Priority	87,917	129,104	180,587	199,976	212,902	219,366	232,292	277,534	309,849	342,165	406,796
-	Indian Priority	47,216	69,335	96,984	107,397	114,339	117,810	124,752	149,049	166,404	183,759	218,469
-	4th Priority i (Mainstream)	14,281	20,971	29,334	32,484	34,584	35,633	37,733	45,082	50,331	55,581	66,079
-	2nd & 3rd Priorities	104,602	153,605	214,858	237,927	253,306	260,996	276,375	330,203	368,651	407,099	483,996
-	1st Priority (Present Perfected Rights)	78,355	115,062	160,946	178,227	189,747	195,507	207,028	247,349	276,150	304,951	362,552
-	**Subtotal**	**370,000**	**543,333**	**760,000**	**841,600**	**896,000**	**923,200**	**977,600**	**1,168,000**	**1,304,000**	**1,440,000**	**1,712,000**
California	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	9,700	22,633	38,800	52,768	62,080	66,736	76,048	108,641	131,921	155,201	201,761
-	3rd Priority (IID, CVWD, PVID)	20,875	48,708	83,500	113,560	133,600	143,620	163,660	233,800	283,900	334,000	434,200
-	2nd Priority (Yuma Project Reservation Division)	182	425	729	992	1,167	1,255	1,430	2,042	2,480	2,918	3,793
-	1st Priority (PVID)	9,209	21,489	36,838	50,099	58,940	63,361	72,202	103,146	125,249	147,351	191,557
-	Present Perfected Rights (PPRs)	70,033	163,411	280,133	380,980	448,212	481,828	549,060	784,371	952,451	1,120,530	1,456,690
-	**Subtotal**	**110,000**	**256,667**	**440,000**	**598,400**	**704,000**	**756,800**	**862,400**	**1,232,000**	**1,496,000**	**1,760,000**	**2,288,000**
Nevada	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	6,181	10,302	15,453	18,543	20,604	21,634	23,694	30,906	36,056	41,207	51,509
-	8th Priority (SNWA & Big Bend)	10,865	18,109	27,163	32,596	36,218	38,029	41,650	54,327	63,381	72,436	90,544
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	150	251	376	451	502	527	577	752	878	1,003	1,254
-	6th Priority (Las Vegas Valley Water District)	534	890	1,335	1,602	1,780	1,869	2,047	2,671	3,116	3,561	4,451
-	5th Priority (PABCO)	32	54	80	97	107	113	123	161	188	214	268
-	4th Priority (Henderson & Basic)	1,353	2,255	3,383	4,060	4,511	4,736	5,187	6,766	7,894	9,022	11,277
-	3rd Priority (Boulder City)	204	340	509	611	679	713	781	1,019	1,188	1,358	1,698

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-	-	600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	2nd Priority (Lake Mead National Rec Area)	100	167	250	300	333	350	383	500	583	667	833
-	1st Priority (PPRs: LMNRA & Fort Mojave Indian Reservation)	580	966	1,450	1,740	1,933	2,029	2,223	2,899	3,382	3,866	4,832
-	**Subtotal**	**20,000**	**33,333**	**50,000**	**60,000**	**66,667**	**70,000**	**76,667**	**100,000**	**116,667**	**133,333**	**166,667**
-	**Lower Basin States Subtotal**	**500,000**	**833,333**	**1,250,000**	**1,500,000**	**1,666,667**	**1,750,000**	**1,916,667**	**2,500,000**	**2,916,667**	**3,333,333**	**4,166,667**
Mexico	**Mexico Subtotal**	**100,000**	**166,667**	**250,000**	**300,000**	**333,333**	**350,000**	**383,333**	**500,000**	**583,333**	**666,667**	**833,333**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

Disclaimer: These modeling results for the Lower Basin Pro Rata should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here

Table C-44
Lower Basin Pro Rata Alternative Distribution Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	3,273	4,806	6,723	7,445	7,926	8,167	8,648	10,332	11,535	12,738	15,144
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	3,881	5,699	7,972	8,828	9,398	9,684	10,254	12,251	13,678	15,104	17,957
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	16,597	24,373	34,092	37,752	40,193	41,413	43,853	52,394	58,495	64,595	76,797
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	550	808	1,131	1,252	1,333	1,374	1,454	1,738	1,940	2,142	2,547
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	26,314	38,641	54,050	59,853	63,722	65,656	69,525	83,066	92,738	102,410	121,754
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	5,202	7,639	10,686	11,833	12,598	12,980	13,745	16,422	18,334	20,246	24,071
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	168	246	344	381	406	418	443	529	591	652	776
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	8,023	11,782	16,481	18,250	19,430	20,020	21,199	25,328	28,277	31,226	37,125
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	2,509	3,685	5,154	5,708	6,077	6,261	6,630	7,921	8,844	9,766	11,611
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	69	101	141	157	167	172	182	217	243	268	318
CAP Indian Priority	San Carlos Apache Tribe	Gila County	1,748	2,567	3,590	3,976	4,233	4,361	4,618	5,517	6,160	6,802	8,087
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	1,830	2,688	3,760	4,163	4,433	4,567	4,836	5,778	6,451	7,124	8,469
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	1,101	1,617	2,261	2,504	2,666	2,747	2,909	3,476	3,880	4,285	5,094
CAP Indian Priority	Tonto Apache Tribe	Gila County	18	26	36	40	43	44	47	56	62	69	82
CAP Indian Priority	Yavapai Apache Nation	Gila County	165	243	339	376	400	412	436	521	582	643	764
CAP M&I Priority	San Carlos Apache Tribe	Gila County	2,497	3,667	5,129	5,680	6,047	6,231	6,598	7,883	8,801	9,719	11,555
4(i)	Hopi Tribe[1]	La Paz County	398	585	818	906	964	993	1,052	1,257	1,403	1,549	1,842
4(i)	Cocopah Indian Reservation	Yuma County	178	261	365	405	431	444	470	562	627	692	823

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	459	674	942	1,043	1,111	1,145	1,212	1,448	1,617	1,785	2,123
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	1,341	1,969	2,754	3,050	3,247	3,346	3,543	4,233	4,726	5,218	6,204
3	Ak-Chin Indian Community[1]	Pinal County	6,554	9,624	13,461	14,907	15,870	16,352	17,315	20,688	23,097	25,506	30,323
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	675	991	1,386	1,534	1,633	1,683	1,782	2,129	2,377	2,625	3,121
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	100	147	206	228	242	250	265	316	353	390	463
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	5,348	7,854	10,986	12,165	12,952	13,345	14,131	16,884	18,850	20,815	24,747
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	1,980	2,907	4,066	4,503	4,794	4,939	5,230	6,249	6,977	7,704	9,160
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	524	770	1,077	1,193	1,270	1,308	1,385	1,655	1,848	2,041	2,426
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	3,543	5,203	7,278	8,059	8,580	8,841	9,362	11,185	12,487	13,790	16,394
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	17,177	25,223	35,282	39,070	41,595	42,858	45,383	54,222	60,536	66,849	79,476
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	24,427	35,871	50,175	55,562	59,154	60,949	64,541	77,111	86,090	95,069	113,026
-	-	**Subtotal**	**136,649**	**200,665**	**280,685**	**310,822**	**330,913**	**340,959**	**361,050**	**431,369**	**481,597**	**531,824**	**632,280**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	153	357	612	833	980	1,053	1,200	1,715	2,082	2,449	3,184
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	226	527	903	1,228	1,445	1,553	1,770	2,528	3,070	3,612	4,695
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	913	2,131	3,652	4,967	5,844	6,282	7,159	10,227	12,418	14,610	18,993
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	85	198	340	462	544	585	666	952	1,156	1,360	1,767
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	583	1,361	2,334	3,174	3,734	4,014	4,575	6,535	7,936	9,336	12,137
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	156	364	623	848	997	1,072	1,221	1,745	2,119	2,493	3,241
-	-	**Subtotal**	**2,116**	**4,938**	**8,465**	**11,512**	**13,544**	**14,559**	**16,591**	**23,701**	**28,780**	**33,859**	**44,017**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	560	933	1,400	1,680	1,866	1,959	2,146	2,799	3,266	3,732	4,665
-	-	**Subtotal**	**560**	**933**	**1,400**	**1,680**	**1,866**	**1,959**	**2,146**	**2,799**	**3,266**	**3,732**	**4,665**
-	-	**Total**	**139,325**	**206,536**	**290,549**	**324,013**	**346,323**	**357,477**	**379,787**	**457,869**	**513,642**	**569,416**	**680,962**
	Summary by County												
-	Coconino County	-	428	629	879	974	1,037	1,068	1,131	1,352	1,509	1,666	1,981
-	Gila County	-	5,575	8,186	11,451	12,680	13,500	13,909	14,729	17,598	19,647	21,696	25,794
-	La Paz County	-	45,545	66,882	93,552	103,597	110,293	113,641	120,338	143,775	160,516	177,257	210,739
-	Maricopa County	-	17,213	25,277	35,357	39,153	41,683	42,949	45,480	54,337	60,664	66,991	79,645
-	Mohave County	-	7,603	11,165	15,617	17,294	18,412	18,971	20,089	24,002	26,796	29,591	35,180
-	Pima County	-	9,152	13,439	18,799	20,817	22,163	22,835	24,181	28,891	32,255	35,619	42,347
-	Pinal County	-	45,716	67,132	93,903	103,985	110,706	114,067	120,788	144,314	161,117	177,921	211,528
-	Yuma County	-	2,818	4,138	5,788	6,409	6,824	7,031	7,445	8,895	9,931	10,966	13,038
-	Apache County	-	1,300	1,909	2,670	2,956	3,148	3,243	3,434	4,103	4,581	5,059	6,014
-	Navajo County	-	1,300	1,909	2,670	2,956	3,148	3,243	3,434	4,103	4,581	5,059	6,014
-	**Subtotal Arizona Tribal**	-	**136,649**	**200,665**	**280,685**	**310,822**	**330,913**	**340,959**	**361,050**	**431,369**	**481,597**	**531,824**	**632,280**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	791	1846	3164	4303	5062	5442	6201	8859	10757	12655	16452
-	Riverside	-	412	962	1649	2242	2638	2835	3231	4616	5605	6594	8,572
-	Imperial	-	913	2131	3652	4967	5844	6282	7159	10227	12418	14610	18993
-	**Subtotal California Tribal**	-	**2116**	**4938**	**8465**	**11512**	**13544**	**14559**	**16591**	**23701**	**28780**	**33859**	**44017**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	560	933	1400	1680	1866	1959	2146	2799	3266	3732	4665
-	**Subtotal Nevada Tribal**	-	**560**	**933**	**1400**	**1680**	**1866**	**1959**	**2146**	**2799**	**3266**	**3732**	**4665**

Disclaimer: These modeling results for the Lower Basin Pro Rata should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and Tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Table C-45
Lower Basin Pro Rata Alternative Distribution Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	268	393	550	609	649	668	708	845	944	1,042	1,239
4(i)	Arizona State Land Department	Yuma County	554	814	1,138	1,261	1,342	1,383	1,464	1,750	1,953	2,157	2,564
4(i)	Beattie Farms, Southwest	Yuma County	95	139	194	215	229	236	250	299	333	368	438
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	39	57	80	89	95	98	103	123	138	152	181
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	12	17	24	27	28	29	31	37	41	46	54
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	179	263	367	407	433	446	473	565	631	696	828
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	20	30	41	46	49	50	53	63	71	78	93
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	693	1,017	1,423	1,575	1,677	1,728	1,830	2,186	2,441	2,696	3,205
4(i)	Curtis, Armon	Yuma County	26	38	52	58	62	64	68	81	90	99	118
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	107	157	220	244	260	268	283	338	378	417	496
4(i)	Matador Farms, LLC	La Paz County	383	563	787	872	928	957	1,013	1,210	1,351	1,492	1,774
4(i)	JRJ Partners, L.L.C.	Yuma County	92	135	189	209	223	230	243	290	324	358	426
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	2,481	3,644	5,097	5,644	6,009	6,192	6,556	7,833	8,746	9,658	11,482
4(i)	North Baja Pipeline, LLC[2]	La Paz County	41	60	84	93	99	102	108	129	144	159	189
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	79	116	162	179	191	196	208	249	277	306	364
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	41	60	84	93	99	102	108	129	144	159	189
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	41	61	85	94	100	103	109	131	146	161	192
4(i)	Red River Land Company, LLC	La Paz County	28	41	57	64	68	70	74	88	98	109	129
4(i)	Phillips, Milton and Jean	Yuma County	8	12	16	18	19	20	21	25	28	31	36
4(i)	Western Water, LLC	La Paz County	51	74	104	115	123	126	134	160	178	197	234
3	Sturges, Harold	Yuma County	44	64	90	100	106	110	116	139	155	171	203
3	Sturges, Irma	Yuma County	50	74	104	115	122	126	133	159	178	196	233
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	18,549	27,239	38,101	42,191	44,919	46,282	49,009	58,555	65,373	72,191	85,826

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	8,818	12,949	18,113	20,058	21,354	22,002	23,299	27,837	31,078	34,319	40,802
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	882	1,296	1,812	2,007	2,136	2,201	2,331	2,785	3,109	3,434	4,082
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	36,438	53,507	74,845	82,881	88,238	90,917	96,274	115,025	128,418	141,811	168,598
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	470	690	964	1,068	1,137	1,172	1,241	1,482	1,655	1,827	2,173
3	Yuma County Water Users' Association (14,701 af M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	10,394	15,264	21,351	23,643	25,171	25,935	27,464	32,813	36,633	40,454	48,095
3	University of Arizona	Yuma County	143	209	293	324	345	356	377	450	503	555	660
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	16	23	32	36	38	39	42	50	55	61	73
3	Unit B Irrigation & Drainage District[3]	Yuma County	2,213	3,250	4,546	5,034	5,360	5,522	5,848	6,987	7,800	8,614	10,241
1	PPR No. 15, Molina	Yuma County	42	61	86	95	101	104	110	132	147	162	193
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	58	86	120	133	141	145	154	184	205	227	270
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	570	838	1,172	1,297	1,381	1,423	1,507	1,801	2,010	2,220	2,639
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	803	1,179	1,649	1,826	1,944	2,003	2,121	2,534	2,829	3,124	3,715
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	22,323	32,781	45,853	50,776	54,058	55,699	58,981	70,469	78,674	86,879	103,290
1	PPR No. 7, Powers	Yuma County	82	120	168	186	198	204	216	258	288	318	378
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	51	75	105	116	123	127	135	161	180	198	236
1	PPR No. 10, Hulet (MVIDD)	Mohave County	76	112	157	174	185	191	202	241	269	297	354
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	74	109	153	169	180	185	196	235	262	289	344
1	PPR No. 12, Miller (MVIDD)	Mohave County	17	25	35	39	41	42	45	54	60	66	79
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	57	84	118	130	139	143	151	181	202	223	265
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	76	112	157	174	185	191	202	241	269	297	354
1	PPR No. 18, Swan (MVIDD)	Mohave County	68	100	140	155	165	170	180	214	239	264	314
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	6	8	11	13	13	14	15	17	19	21	25
-	-	**Subtotal**	**107,558**	**157,945**	**220,930**	**244,651**	**260,465**	**268,371**	**284,185**	**339,534**	**379,069**	**418,604**	**497,673**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	125	292	500	680	800	860	980	1,400	1,700	2,000	2,600
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	8,250	19,250	33,000	44,880	52,800	56,760	64,680	92,400	112,200	132,000	171,600
3	Imperial Irrigation District (IID) (3a)	Imperial County	12,500	29,167	50,000	68,000	80,000	86,000	98,000	140,000	170,000	200,000	260,000
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	182	425	729	992	1,167	1,255	1,430	2,042	2,480	2,918	3,793
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	9,209	21,489	36,838	50,099	58,940	63,361	72,202	103,146	125,249	147,351	191,557
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	3	7	12	16	18	20	23	32	39	46	60
PPR	PPR No. 41, Chagnon	San Bernardino	2	4	8	10	12	13	15	22	26	31	40
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	2	4	6	8	10	11	12	17	21	25	32
PPR	PPR No. 34, Milpitas	Imperial County	2	4	7	9	11	12	14	19	24	28	36
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	488	1,139	1,952	2,654	3,123	3,357	3,825	5,465	6,636	7,807	10,149
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	65,000	151,667	260,000	353,600	416,000	447,200	509,600	728,000	884,000	1,040,000	1,352,000
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	2,363	5,513	9,451	12,853	15,121	16,255	18,523	26,462	32,132	37,802	49,143
PPR	PPR No. 42, Lawrence	Imperial County	2	4	8	10	12	13	15	22	26	31	40
PPR	PPR No. 37, Milpitas	Imperial County	1	3	4	6	7	8	9	12	15	18	23
PPR	PPR No. 33, Morgan	Imperial County	2	6	10	13	15	17	19	27	33	38	50
PPR	PPR No. 35, Simons	San Bernardino	1	2	4	5	6	7	8	11	13	15	20
-	-	**Subtotal**	**98,132**	**228,974**	**392,527**	**533,837**	**628,044**	**675,147**	**769,354**	**1,099,076**	**1,334,593**	**1,570,109**	**2,041,142**
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**205,690**	**386,920**	**613,457**	**778,488**	**888,508**	**943,518**	**1,053,539**	**1,438,611**	**1,713,662**	**1,988,713**	**2,538,815**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	1,534	2,253	3,151	3,490	3,715	3,828	4,053	4,843	5,407	5,971	7,099
-	Mohave County	-	2,902	4,261	5,961	6,601	7,027	7,241	7,667	9,161	10,227	11,294	13,427
-	Yuma County	-	103,122	151,431	211,818	234,560	249,722	257,303	272,465	325,531	363,435	401,339	477,148
-	**Subtotal Arizona Irrigation**	-	**107,558**	**157,945**	**220,930**	**244,651**	**260,465**	**268,371**	**284,185**	**339,534**	**379,069**	**418,604**	**497,673**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	14,161	33,042	56,644	77,036	90,631	97,428	111,023	158,604	192,590	226,577	294,550
-	Imperial County	-	83,966	195,922	335,865	456,777	537,385	577,689	658,296	940,423	1,141,943	1,343,462	1,746,500
-	San Bernardino	-	4	10	18	24	28	30	35	49	60	71	92
-	**Subtotal California Irrigation**	-	**98,132**	**228,974**	**392,527**	**533,837**	**628,044**	**675,147**	**769,354**	**1,099,076**	**1,334,593**	**1,570,109**	**2,041,142**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

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Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Table C-46
Lower Basin Pro Rata Alternative Distribution Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	383	563	788	872	928	957	1,013	1,210	1,351	1,492	1,774
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	2,503	3,675	5,141	5,693	6,061	6,245	6,613	7,900	8,820	9,740	11,580
CAP NIA-B	Carefree Water Company	Maricopa County	15	23	32	35	37	38	41	49	54	60	71
CAP NIA-B	Cave Creek	Maricopa County	53	78	109	121	129	133	140	168	187	207	246
CAP NIA-B	El Mirage	Maricopa County	181	266	373	413	439	453	479	573	639	706	839
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	443	650	909	1,007	1,072	1,105	1,170	1,398	1,560	1,723	2,049
CAP NIA-B	Freeport	Pima County	781	1,148	1,605	1,777	1,892	1,950	2,065	2,467	2,754	3,041	3,616
CAP NIA-B	Gilbert	Maricopa County	252	370	518	573	611	629	666	796	889	981	1,167
CAP NIA-B	Marana	Pima County	71	104	146	161	172	177	187	224	250	276	328
CAP NIA-B	Queen Creek	Maricopa County	573	841	1,177	1,303	1,387	1,429	1,513	1,808	2,019	2,229	2,650
CAP NIA-B	Resolution Copper	Maricopa County	308	452	633	701	746	769	814	972	1,085	1,199	1,425
CAP NIA-B	Rosemont Copper	Pima County	155	227	318	352	375	386	409	488	545	602	716
CAP NIA-B	SRP	Maricopa County	297	437	611	676	720	742	785	938	1,048	1,157	1,375
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	112	165	231	256	272	281	297	355	396	438	520
CAP NIA-A	Phoenix	Maricopa County	5,131	7,534	10,539	11,670	12,424	12,802	13,556	16,196	18,082	19,968	23,740
CAP NIA-A	Chandler	Maricopa County	540	793	1,109	1,228	1,308	1,347	1,427	1,705	1,903	2,102	2,499
CAP NIA-A	Gilbert	Maricopa County	212	311	434	481	512	528	559	668	745	823	979
CAP NIA-A	Glendale	Maricopa County	94	138	193	213	227	234	248	296	331	365	434
CAP NIA-A	Mesa	Maricopa County	764	1,122	1,569	1,738	1,850	1,906	2,018	2,412	2,692	2,973	3,535
CAP NIA-A	Scottsdale	Maricopa County	455	668	935	1,035	1,102	1,135	1,202	1,436	1,604	1,771	2,105

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Tempe	Maricopa County	3	5	7	7	8	8	8	10	11	12	15
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	69	101	141	157	167	172	182	217	243	268	318
CAP M&I	ASARCO	Pima County	2,890	4,244	5,936	6,574	6,999	7,211	7,636	9,123	10,186	11,248	13,373
CAP M&I	Avondale	Maricopa County	745	1,095	1,531	1,695	1,805	1,860	1,969	2,353	2,627	2,901	3,449
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	3,878	5,694	7,965	8,820	9,390	9,675	10,245	12,241	13,666	15,092	17,942
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	1,223	1,795	2,511	2,781	2,961	3,051	3,230	3,860	4,309	4,758	5,657
CAP M&I	Arizona Water Company, Coolidge	Pinal County	275	404	565	626	667	687	727	869	970	1,071	1,274
CAP M&I	Arizona Water Company, Superstition	Pinal County	865	1,270	1,777	1,967	2,095	2,158	2,285	2,730	3,048	3,366	4,002
CAP M&I	Arizona Water Company, White Tank	Maricopa County	133	196	274	303	323	332	352	421	470	518	616
CAP M&I	Buckeye	Maricopa County	9	14	19	21	23	23	25	30	33	36	43
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	884	1,299	1,817	2,012	2,142	2,207	2,337	2,792	3,117	3,442	4,092
CAP M&I	Carefree Water Company	Maricopa County	231	339	474	525	559	576	610	729	814	899	1,069
CAP M&I	Cave Creek	Maricopa County	307	450	630	697	743	765	810	968	1,081	1,193	1,419
CAP M&I	Chandler	Maricopa County	1,191	1,749	2,446	2,709	2,884	2,972	3,147	3,760	4,197	4,635	5,511
CAP M&I	Chaparral City Water Company	Maricopa County	1,226	1,800	2,518	2,789	2,969	3,059	3,240	3,870	4,321	4,772	5,673
CAP M&I	Circle City	Maricopa County	541	795	1,112	1,231	1,310	1,350	1,430	1,708	1,907	2,106	2,504
CAP M&I	El Mirage	Maricopa County	70	103	144	159	169	174	185	221	246	272	323
CAP M&I	Eloy	Pinal County	299	439	614	680	724	746	789	943	1,053	1,163	1,382
CAP M&I	EPCOR, Agua Fria	Maricopa County	1,527	2,242	3,136	3,473	3,697	3,809	4,034	4,819	5,380	5,942	7,064
CAP M&I	EPCOR, Paradise Valley	Maricopa County	445	653	913	1,011	1,077	1,109	1,175	1,404	1,567	1,731	2,057
CAP M&I	EPCOR, Sun City	Maricopa County	577	847	1,184	1,311	1,396	1,438	1,523	1,820	2,032	2,244	2,668
CAP M&I	EPCOR, Sun City West	Maricopa County	326	479	671	743	791	815	863	1,031	1,150	1,270	1,510
CAP M&I	Florence	Pinal County	282	414	579	641	683	703	745	890	993	1,097	1,304
CAP M&I	Freeport-Miami	Gila County	400	587	821	910	968	998	1,057	1,262	1,410	1,557	1,851

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	393	577	807	893	951	980	1,038	1,240	1,384	1,529	1,817
CAP M&I	Gilbert	Maricopa County	996	1,462	2,045	2,265	2,411	2,484	2,631	3,143	3,509	3,875	4,607
CAP M&I	Glendale	Maricopa County	2,372	3,483	4,872	5,396	5,744	5,919	6,267	7,488	8,360	9,232	10,976
CAP M&I	Goodyear	Maricopa County	1,478	2,171	3,037	3,363	3,580	3,689	3,906	4,667	5,210	5,754	6,840
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	9	13	18	20	21	22	23	28	31	34	41
CAP M&I	Green Valley Community Water Company	Pima County	393	578	808	895	952	981	1,039	1,242	1,386	1,531	1,820
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	261	384	537	595	633	652	691	825	922	1,018	1,210
CAP M&I	Marana	Pima County	321	472	660	731	779	802	849	1,015	1,133	1,251	1,488
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	92	134	188	208	222	228	242	289	323	356	423
CAP M&I	Mesa	Maricopa County	5,987	8,792	12,298	13,618	14,498	14,939	15,819	18,900	21,100	23,301	27,702
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	1,852	2,720	3,805	4,213	4,486	4,622	4,894	5,848	6,529	7,209	8,571
CAP M&I	Oro Valley	Pima County	1,418	2,083	2,913	3,226	3,434	3,539	3,747	4,477	4,998	5,520	6,562
CAP M&I	Peoria	Maricopa County	3,732	5,481	7,667	8,490	9,039	9,313	9,862	11,783	13,155	14,526	17,270
CAP M&I	Phoenix	Maricopa County	17,355	25,485	35,648	39,475	42,027	43,303	45,855	54,785	61,164	67,543	80,302
CAP M&I	Pine	Gila County	22	33	46	50	54	55	59	70	78	86	103
CAP M&I	Queen Creek	Maricopa County	68	100	140	155	165	170	180	215	240	265	315
CAP M&I	Rio Verde Utilities	Maricopa County	112	164	230	254	271	279	295	353	394	435	517
CAP M&I	San Tan Irrigation District	Maricopa County	32	48	67	74	79	81	86	103	114	126	150
CAP M&I	Scottsdale	Maricopa County	7,268	10,673	14,929	16,532	17,600	18,134	19,203	22,943	25,615	28,286	33,629
CAP M&I	Spanish Trail Water Company	Pima County	418	614	859	951	1,012	1,043	1,104	1,319	1,473	1,627	1,934
CAP M&I	Surprise	Maricopa County	1,411	2,071	2,897	3,208	3,416	3,519	3,727	4,453	4,971	5,490	6,526
CAP M&I	Tempe	Maricopa County	594	872	1,220	1,351	1,438	1,482	1,569	1,875	2,093	2,311	2,748
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	10	14	20	22	24	24	26	31	34	38	45
CAP M&I	Tucson	Pima County	19,844	29,140	40,761	45,137	48,055	49,514	52,431	62,643	69,937	77,231	91,819

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Vail Water Company	Pima County	256	375	525	581	619	638	675	807	901	995	1,183
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	402	590	825	914	973	1,002	1,061	1,268	1,416	1,563	1,859
4(i)	Arizona State Land Department	Yuma County	129	189	264	293	312	321	340	406	454	501	595
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	8	11	16	17	19	19	20	24	27	30	35
4(i)	B&F Investment, LLC	La Paz County	5	8	11	12	13	14	14	17	19	21	25
4(i)	Bullhead City	Mohave County	1,316	1,932	2,703	2,993	3,186	3,283	3,476	4,154	4,637	5,121	6,088
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	185	272	380	421	448	462	489	584	652	720	856
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	606	889	1,244	1,377	1,466	1,511	1,600	1,912	2,134	2,357	2,802
4(i)	Bureau of Land Management	La Paz County	526	772	1,080	1,195	1,273	1,311	1,389	1,659	1,852	2,045	2,432
4(i)	Crystal Beach Water Conservation District	Mohave County	11	17	23	26	27	28	30	36	40	44	52
4(i)	Ehrenburg Improvement District	La Paz County	61	89	125	138	147	151	160	192	214	236	281
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	162	238	333	369	393	404	428	512	571	631	750
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	5	7	10	11	11	12	12	15	16	18	22
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	0	0	0	0	0	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	1	1	2	2	2	2	2	3	3	4	4
4(i)	Golden Shores Water Conservation District	Mohave County	176	258	361	399	425	438	464	554	619	684	813
4(i)	GSC Farm, LLC	La Paz County	7	10	14	15	16	16	17	21	23	26	31
4(i)	Hillcrest Water Company	La Paz County	7	11	15	16	17	18	19	23	25	28	33
4(i)	Lake Havasu City	Mohave County	1,560	2,290	3,204	3,548	3,777	3,892	4,121	4,923	5,497	6,070	7,217
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	174	255	357	395	421	434	459	549	613	676	804
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	589	865	1,210	1,340	1,427	1,470	1,557	1,860	2,076	2,293	2,726
4(i)	La Paz County	La Paz County	46	67	94	104	111	114	121	145	162	179	212
4(i)	Martinez Lake Cabin Sites	Yuma County	2	3	4	4	5	5	5	6	7	8	9

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	McAlister Family Trust	Mohave County	4	5	7	8	9	9	10	11	13	14	17
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	88	130	182	201	214	221	234	279	312	344	409
4(i)	Mohave Water Conservation District	Mohave County	158	232	325	360	383	394	418	499	557	615	731
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	263	387	541	599	638	657	696	832	928	1,025	1,219
4(i)	Parker, Town of[1]	La Paz County	57	83	116	129	137	141	150	179	200	221	262
4(i)	Quartzsite, Town of	La Paz County	140	206	288	319	340	350	371	443	494	546	649
4(i)	Queen Creek, Town of	Maricopa County	266	391	547	606	645	665	704	841	939	1,037	1,233
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	0	0	0	0	0	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	4	6	9	10	10	11	11	13	15	17	20
4(i)	Somerton, City of	Yuma County	98	144	202	224	238	245	260	310	346	383	455
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	10	14	20	22	23	24	25	30	34	37	44
4(i)	TV Marble Canyon AZ, LLC	Coconino County	6	9	12	14	14	15	16	19	21	23	28
3	City of Yuma[1]	Yuma County	6,360	9,339	13,063	14,466	15,401	15,869	16,804	20,076	22,414	24,752	29,427
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	3	5	7	8	8	8	9	11	12	13	15
3	Kaman, Inc.	Yuma County	0	0	1	1	1	1	1	1	1	1	1
3	Department of the Navy, MCAS	Yuma County	393	577	808	894	952	981	1,039	1,241	1,386	1,530	1,819
3	City of Yuma (cemetery)	Yuma County	8	12	16	18	19	20	21	25	28	31	36
3	Yuma Mesa Fruit Growers' Association	Yuma County	2	3	4	4	5	5	5	6	7	8	9
3	Desert Lawn Memorial Park Association	Yuma County	18	27	37	41	44	45	48	57	64	70	84
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	561	823	1,152	1,275	1,358	1,399	1,482	1,770	1,976	2,182	2,594
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	886	1,302	1,821	2,016	2,146	2,211	2,342	2,798	3,124	3,449	4,101
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	393	577	808	894	952	981	1,039	1,241	1,386	1,530	1,819
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	362	531	743	823	876	903	956	1,142	1,275	1,408	1,674

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	655	962	1,346	1,491	1,587	1,635	1,732	2,069	2,310	2,551	3,032
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	13	19	27	30	32	33	35	41	46	51	61
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	13	19	27	30	32	33	35	41	46	51	61
3	Department of the Army - Yuma Proving Ground	Yuma County	148	217	304	337	358	369	391	467	522	576	685
3	Yuma Union High School District	Yuma County	19	28	40	44	47	48	51	61	68	75	90
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	33	48	67	74	79	81	86	103	115	127	151
2	Cibola National Wildlife Refuge	La Paz County	2,201	3,232	4,521	5,007	5,330	5,492	5,816	6,948	7,757	8,566	10,184
2	Lake Mead National Recreation Area	Mohave County	45	66	92	102	109	112	119	142	158	175	208
2	Bureau of Reclamation - Davis Dam	Mohave County	1	1	2	2	2	2	2	3	3	4	4
2	Imperial National Wildlife Refuge	La Paz County	3,015	4,427	6,192	6,857	7,300	7,522	7,965	9,516	10,624	11,733	13,949
2	Havasu Lake National Wildlife Refuge	Mohave County	4,902	7,198	10,069	11,150	11,871	12,231	12,952	15,474	17,276	19,078	22,681
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	31	46	64	71	75	78	82	98	110	121	144
1	PPR No. 20, Parker, City of	La Paz County	52	77	108	119	127	131	139	166	185	204	243
1	PPR No. 21, Yuma, City of	Yuma County	194	284	398	441	469	483	512	612	683	754	896
-	-	**Subtotal**	**125,793**	**184,723**	**258,385**	**286,128**	**304,623**	**313,870**	**332,365**	**397,097**	**443,335**	**489,572**	**582,047**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	9,700	22,633	38,800	52,768	62,080	66,736	76,048	108,641	131,921	155,201	201,761
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	0

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 30, Stephenson	San Bernardino	4	9	15	21	25	26	30	43	52	61	80
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 38, Andrade	San Bernardino	1	2	4	6	7	7	8	12	14	17	22
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	1	2	4	5	6	7	8	11	13	15	20
PPR	PPR No. 39, Reynolds	San Bernardino	1	1	2	3	4	4	5	6	8	9	12
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	7	16	27	37	44	47	54	76	93	109	142
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	2	4	8	10	12	13	15	22	26	31	40
PPR	PPR No. 43, City of Needles	San Bernardino	24	55	95	129	152	163	186	266	323	380	494
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	12	29	50	68	80	86	98	140	170	200	260
-	-	**Subtotal**	**9,752**	**22,755**	**39,008**	**53,051**	**62,413**	**67,094**	**76,456**	**109,222**	**132,627**	**156,032**	**202,841**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	6,181	10,302	15,453	18,543	20,604	21,634	23,694	30,906	36,056	41,207	51,509
8	Big Bend Water District	Clark	327	544	817	980	1,089	1,143	1,252	1,633	1,906	2,178	2,722
8	Robert B. Griffith Project	Clark	10,539	17,564	26,347	31,616	35,129	36,885	40,398	52,693	61,476	70,258	87,822

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	1	1	1	1	1	1	2	2	2	3
7	Bureau of Reclamation (includes Sportsman Park)	Clark	10	16	25	29	33	34	38	49	57	65	82
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	2	3	4	5	6	6	6	8	10	11	14
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	139	231	347	416	462	485	532	693	809	924	1,156
6	Las Vegas Valley Water District	Clark	534	890	1,335	1,602	1,780	1,869	2,047	2,671	3,116	3,561	4,451
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	32	54	80	97	107	113	123	161	188	214	268
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	285	474	711	854	948	996	1,091	1,423	1,660	1,897	2,371
4	City of Henderson	Clark	550	917	1,376	1,651	1,835	1,927	2,110	2,752	3,211	3,670	4,587
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	518	864	1,296	1,555	1,728	1,814	1,987	2,591	3,023	3,455	4,319
3	Boulder City	Clark	204	340	509	611	679	713	781	1,019	1,188	1,358	1,698
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	100	167	250	300	333	350	383	500	583	667	833
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	20	33	50	60	67	70	77	100	117	133	167
-	-	**Subtotal**	**19,440**	**32,400**	**48,600**	**58,320**	**64,800**	**68,041**	**74,521**	**97,201**	**113,401**	**129,601**	**162,001**
-	-	**Total**	**154,985**	**239,878**	**345,994**	**397,499**	**431,836**	**449,004**	**483,341**	**603,520**	**689,363**	**775,205**	**946,889**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	6	9	12	14	14	15	16	19	21	23	28
-	Gila County	-	422	620	867	960	1,022	1,053	1,115	1,332	1,488	1,643	1,953
_	La Paz County	-	6,157	9,042	12,647	14,005	14,910	15,363	16,268	19,437	21,700	23,963	28,490
_	Maricopa County	-	68,589	100,720	140,885	156,011	166,095	171,138	181,222	216,517	241,728	266,939	317,361
_	Mohave County	-	10,247	15,047	21,048	23,308	24,814	25,568	27,074	32,347	36,114	39,880	47,413
_	Pima County	-	29,054	42,666	59,679	66,087	70,359	72,495	76,767	91,718	102,397	113,077	134,436
_	Pinal County	-	3,900	5,728	8,012	8,872	9,445	9,732	10,305	12,313	13,746	15,180	18,047
_	Yuma County	-	7,417	10,892	15,235	16,871	17,961	18,507	19,597	23,414	26,140	28,866	34,319
_	**Subtotal Arizona Domestic**	-	**125,793**	**184,723**	**258,385**	**286,128**	**304,623**	**313,870**	**332,365**	**397,097**	**443,335**	**489,572**	**582,047**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Lower Basin Pro Rata (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
_	**California**	-	-	-	-	-	-	-	-	-	-	-	-
_	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	9,700	22,633	38,800	52,768	62,080	66,736	76,048	108,641	131,921	155,201	201,761
_	Imperial County	-	15	35	59	81	95	102	116	166	202	238	309
_	Riverside County	-	0	0	0	0	0	1	1	1	1	1	2
_	San Bernardino	-	37	86	148	201	237	255	290	415	503	592	770
_	**Subtotal California Domestic**	-	**9,752**	**22,755**	**39,008**	**53,051**	**62,413**	**67,094**	**76,456**	**109,222**	**132,627**	**156,032**	**202,841**
_	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
_	Clark	-	19,440	32,400	48,600	58,320	64,800	68,041	74,521	97,201	113,401	129,601	162,001
_	**Subtotal Nevada Domestic**	-	**19,440**	**32,400**	**48,600**	**58,320**	**64,800**	**68,041**	**74,521**	**97,201**	**113,401**	**129,601**	**162,001**

Disclaimer: These modeling results for the Lower Basin Pro Rata should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]This user also holds a PPR entitlement.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

C.10 Pro Rata Without Tribal Shortage Alternative Distribution Model

The Pro Rata Without Tribal Shortage Alternative Distribution Model is an adaptation of the Pro Rata Alternative Distribution Model that represents a distribution of shortages to all users except tribes. It simulates shortages and distributes water on a proportional basis (i.e., at the same percentage reduction from each user's entitlement) across all non-tribal lower Colorado River water entitlements, and assumes all tribal entitlements are fully satisfied and are never shorted.

Assumptions for this Alternative Distribution Model are the same as for the Pro Rata Alternative Distribution Model unless described otherwise below. This Alternative Distribution Model reflects a modeling commitment to display a distribution of water during shortage that does not short tribal entitlements/allocations. It is not an interpretation of law, contracts, or a legal position.

The Excel workbook contains formulas extending into deep shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.10.1 Entitlements Which are Not Shorted in the Pro Rata Without Tribal Shortage Alternative Distribution Model

For modeling purposes, the tribal entitlements/allocations in the following **Table C-47** have been removed from the distribution of shortage in this Alternative Distribution Model. The priority of these entitlements is only identified in the Excel workbook and the table below for the purpose of cross-reference. Note that CAP allocations are shown as mainstream consumptive use equivalents, with 5 percent for CAP system loss added to the contract volume. All other entitlements are shown as calculated for the Priority Shortage Allocation Model.

Table C-47
Entitlements and Allocations Not Shorted Under this Alternative Shortage Distribution

State	Priority	Entitlement Holder, Contractor, or Subcontractor	Consumptive Use or Equivalent Entitlement (af)*
Arizona	CAP NIA-B	White Mountain Apache Tribe	24,971.10
Arizona	CAP NIA-A	Gila River Indian Community	126,630.00
Arizona	CAP NIA-A	Tohono O'odham - Schuk Toak & San Xavier	29,610.00
Arizona	CAP NIA-A	Hualapai Tribe**	4,200.00
Arizona	CAP M&I	San Carlos Apache Tribe	19,052.25
Arizona	CAP Indian	Gila River Indian Community	200,760.00
Arizona	CAP Indian	Tohono O'odham Nation (ST & SX)	39,690.00
Arizona	CAP Indian	White Mountain Apache Tribe	1,278.90

State	Priority	Entitlement Holder, Contractor, or Subcontractor	Consumptive Use or Equivalent Entitlement (af)*
Arizona	CAP Indian	Ak-Chin Indian Community	61,215.00
Arizona	CAP Indian	Fort McDowell Yavapai Nation	19,144.65
Arizona	CAP Indian	Pascua Yaqui Tribe	525.00
Arizona	CAP Indian	San Carlos Apache Tribe	13,335.00
Arizona	CAP Indian	Salt River Pima-Maricopa Indian Community	13,965.00
Arizona	CAP Indian	Tohono O'odham Nation Sif Oidak District	8,400.00
Arizona	CAP Indian	Tonto Apache Tribe	134.40
Arizona	CAP Indian	Yavapai Apache Nation	1,260.00
Arizona	P4(i)	Cocopah Indian Reservation	1,357.42
Arizona	P4(i)	Hopi Tribe	3,037.38
Arizona	P4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	3,500.00
Arizona	P4(i)	Unallocated 4th Priority Mainstream Water	10,230.00
Arizona	P3	Ak-Chin Indian Community	50,000.00
Arizona	PPR	Cocopah Indian Reservation	5,146.27
Arizona	PPR	United States (Cocopah Indian Tribe)	763.80
Arizona	PPR	Fort Mojave Indian Reservation	40,805.64
Arizona	PPR	Fort Mojave Indian Reservation	15,103.26
Arizona	PPR	Fort Yuma Indian Reservation	4,000.50
Arizona	PPR	Colorado River Indian Reservation	27,032.72
Arizona	PPR	Colorado River Indian Reservation	131,048.32
Arizona	PPR	Colorado River Indian Reservation	186,368.00
-	-	**Subtotal**	**1,042,564.61**
California	PPR	Chemehuevi Indian Reservation	6,123.60
California	PPR	Fort Mojave Indian Reservation	9,028.80
California	PPR	Fort Yuma Indian Reservation	36,524.16
California	PPR	Colorado River Indian Reservation	3,398.80
California	PPR	Colorado River Indian Reservation	23,339.78
California	PPR	Colorado River Indian Reservation	6,232.10
-	-	**Subtotal**	**84,647.24**
Nevada	P1 (PPR)	Fort Mojave Indian Reservation	8,397.78
-	-	**Subtotal**	**8,397.78**
-	-	**Total**	**1,135,609.63**

*CAP allocations are shown as mainstream consumptive use equivalents, with 5 percent for CAP system loss added to the Contract volume.

** May at some time be diverted from the Colorado River above Lake Mead.

C.10.2 Distribution Among Water Users

Shortage in this Alternative Distribution Model is distributed among only the remaining non-tribal entitlements after the tribal entitlements described above are set aside and assumed to be fully filled.

Each non-tribal entitlement's percentage share of the total shortage is calculated as the ratio of the non-tribal entitlement to the sum of all non-tribal entitlements, including a proportional component[28] for Mexico. The resulting percentages are multiplied by the volume of total shortage to determine the volume of shortage assigned to each entitlement. At a given level of shortage, as a consequence of how that shortage is distributed as described in this paragraph, all non-tribal entitlements bear the same percentage reduction. The volume of shortage assigned to a water user with entitlements in different priority categories is the sum across multiple line items in the model; designations of priority do not affect the function of this Alternative Distribution Model, but are retained to facilitate comparison of the results between models. Entitlements subject to shortage in this Alternative Distribution Model are summarized in the following **Table C-48**.

Table C-48
Non-Tribal Entitlements Subject to Shortage Under this Alternative Distribution Model

Arizona, California, Nevada, and Mexico Summary	CU Equivalent (afy)
Arizona Total	1,780,346
California Total	4,315,353
Nevada Total	291,602
Mexico Total	1,272,878
Total	**7,660,179**

C.10.3 Pro Rata Without Tribal Shortage Alternative Distribution Model Results

The tables in this section present the results of the Pro Rata Without Tribal Shortage Alternative Distribution Model over a range of total shortages to the Lower Basin including Mexico.

Table C-49, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-50, the Tribal Summary, presents the shortage impacts on tribes.

Table C-51, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-52, the Domestic Summary, presents the shortage impacts on domestic users.

[28] A non-shorted component is set aside for Mexico in proportion to the non-shorted Tribal entitlements in the U.S.; in this model, 15.14 percent of 1,500,000 afy, or 227,122 afy.

Table C-49
Pro Rata Without Tribal Shortage Alternative Distribution Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-	-	600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion[2]	-	-	-	-	-	-	-	-	-	-	-
-	NIA Priority	7,964	13,273	19,910	23,892	26,546	27,874	30,528	39,819	46,456	53,093	66,366
-	M&I Priority	51,047	85,078	127,617	153,140	170,156	178,664	195,679	255,234	297,773	340,312	425,389
-	Indian Priority	41	69	103	123	137	144	158	206	240	274	343
-	4th Priority i (Mainstream)	7,115	11,858	17,787	21,344	23,716	24,901	27,273	35,574	41,502	47,431	59,289
-	2nd & 3rd Priorities	58,593	97,656	146,483	175,780	195,311	205,077	224,608	292,967	341,794	390,622	488,278
-	1st Priority (Present Perfected Rights)	14,690	24,483	36,724	44,069	48,966	51,414	56,310	73,448	85,690	97,931	122,414
-	**Subtotal**	**139,449**	**232,416**	**348,624**	**418,348**	**464,831**	**488,073**	**534,556**	**697,247**	**813,455**	**929,663**	**1,162,079**
California	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	30,391	50,652	75,978	91,173	101,304	106,369	116,499	151,955	177,281	202,607	253,259
-	3rd Priority (IID, CVWD, PVID)	65,403	109,005	163,508	196,210	218,011	228,911	250,712	327,016	381,518	436,021	545,026
-	2nd Priority (Yuma Project Reservation Division)	571	952	1,428	1,714	1,904	2,000	2,190	2,857	3,333	3,809	4,761
-	1st Priority (PVID)	28,854	48,090	72,135	86,562	96,180	100,989	110,607	144,270	168,315	192,360	240,450
-	Present Perfected Rights (PPRs)	212,790	354,650	531,974	638,369	709,299	744,764	815,694	1,063,949	1,241,273	1,418,598	1,773,248
-	**Subtotal**	**338,009**	**563,349**	**845,023**	**1,014,028**	**1,126,698**	**1,183,032**	**1,295,702**	**1,690,046**	**1,971,721**	**2,253,395**	**2,816,744**
Nevada	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	7,262	12,104	18,156	21,787	24,207	25,418	27,839	36,311	42,363	48,415	60,519
-	8th Priority (SNWA & Big Bend)	12,766	21,276	31,914	38,297	42,553	44,680	48,935	63,829	74,467	85,105	106,381
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	177	295	442	530	589	619	678	884	1,031	1,179	1,473
-	6th Priority (Las Vegas Valley Water District)	628	1,046	1,569	1,883	2,092	2,196	2,406	3,138	3,661	4,184	5,229
-	5th Priority (PABCO)	38	63	94	113	126	132	145	189	220	252	315
-	4th Priority (Henderson & Basic)	1,590	2,650	3,975	4,770	5,300	5,565	6,095	7,950	9,275	10,600	13,250
-	3rd Priority (Boulder City)	239	399	598	718	798	838	917	1,197	1,396	1,596	1,994

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-	**-**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	2nd Priority (Lake Mead National Rec Area)	117	196	294	352	392	411	450	587	685	783	979
-	1st Priority (PPR: LMNRA)	23	39	59	70	78	82	90	117	137	157	196
-	**Subtotal**	**22,840**	**38,067**	**57,101**	**68,521**	**76,135**	**79,941**	**87,555**	**114,202**	**133,235**	**152,269**	**190,336**
-	**Lower Division States Subtotal**	**500,299**	**833,832**	**1,250,748**	**1,500,897**	**1,667,664**	**1,751,047**	**1,917,813**	**2,501,495**	**2,918,411**	**3,335,327**	**4,169,159**
Mexico	**Mexico Subtotal**	**99,701**	**166,168**	**249,252**	**299,103**	**332,336**	**348,953**	**382,187**	**498,505**	**581,589**	**664,673**	**830,841**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

Disclaimer: These modeling results for the pro rata (w/o Tribal Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here
[2]The CAP priority system is not maintained in the pro rata distribution. CAP contractors and subcontractors are shorted pro rata with non-CAP water users; therefore, there is not an Available CAP Supply calculated for the pro rata alternative distribution model, or a shortage volume given for CAP as a whole.

Table C-50
Pro Rata Without Tribal Shortage Alternative Distribution Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	San Carlos Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Tonto Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP Indian Priority	Yavapai Apache Nation	Gila County	0	0	0	0	0	0	0	0	0	0	0
CAP M&I Priority	San Carlos Apache Tribe	Gila County	0	0	0	0	0	0	0	0	0	0	0
4(i)	Hopi Tribe[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
4(i)	Cocopah Indian Reservation	Yuma County	0	0	0	0	0	0	0	0	0	0	0
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	0	0	0	0	0	0	0	0	0	0	0
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	0	0	0	0	0	0	0	0	0	0	0

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Ak-Chin Indian Community[1]	Pinal County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	Gila County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	0	0	0	0	0	0	0	0	0	0	0
-	Maricopa County	-	0	0	0	0	0	0	0	0	0	0	0
-	Mohave County	-	0	0	0	0	0	0	0	0	0	0	0
-	Pima County	-	0	0	0	0	0	0	0	0	0	0	0
-	Pinal County	-	0	0	0	0	0	0	0	0	0	0	0
-	Yuma County	-	0	0	0	0	0	0	0	0	0	0	0
-	Apache County	-	0	0	0	0	0	0	0	0	0	0	0
-	Navajo County	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Arizona Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
-	Riverside	-	0	0	0	0	0	0	0	0	0	0	0
-	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	0	0	0	0	0	0	0	0	0	0	0
-	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Disclaimer: These modeling results for the pro rata (w/o Tribal Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and Tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Table C-51
Pro Rata Without Tribal Shortage Alternative Distribution Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	160	267	400	480	534	560	614	800	934	1,067	1,334
4(i)	Arizona State Land Department	Yuma County	331	552	828	994	1,104	1,159	1,270	1,656	1,932	2,208	2,760
4(i)	Beattie Farms, Southwest	Yuma County	57	94	141	170	188	198	217	283	330	377	471
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	23	39	58	70	78	82	90	117	136	156	195
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	7	12	18	21	23	25	27	35	41	47	58
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	107	178	267	321	356	374	410	535	624	713	891
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	12	20	30	36	40	42	46	60	70	80	100
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	414	690	1,035	1,242	1,380	1,449	1,587	2,069	2,414	2,759	3,449
4(i)	Curtis, Armon	Yuma County	15	25	38	46	51	53	59	76	89	102	127
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	64	107	160	192	214	224	246	320	374	427	534
4(i)	Matador Farms, LLC	La Paz County	229	382	573	687	764	802	878	1,146	1,336	1,527	1,909
4(i)	JRJ Partners, L.L.C.	Yuma County	55	92	137	165	183	192	211	275	321	367	458
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	1,483	2,472	3,707	4,449	4,943	5,190	5,685	7,415	8,650	9,886	12,358
4(i)	North Baja Pipeline, LLC[2]	La Paz County	24	41	61	73	81	86	94	122	143	163	204
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	47	78	118	141	157	165	180	235	274	314	392
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	24	41	61	73	81	86	94	122	143	163	204
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	25	41	62	74	82	87	95	124	144	165	206
4(i)	Red River Land Company, LLC	La Paz County	17	28	42	50	56	58	64	83	97	111	139
4(i)	Phillips, Milton and Jean	Yuma County	5	8	12	14	16	16	18	23	27	31	39
4(i)	Western Water, LLC	La Paz County	30	50	76	91	101	106	116	151	176	202	252
3	Sturges, Harold	Yuma County	26	44	66	79	87	92	101	131	153	175	219
3	Sturges, Irma	Yuma County	30	50	75	90	101	106	116	151	176	201	251
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	11,085	18,475	27,712	33,254	36,949	38,797	42,492	55,424	64,661	73,899	92,373
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	5,270	8,783	13,174	15,809	17,566	18,444	20,200	26,348	30,740	35,131	43,914

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	527	879	1,318	1,582	1,757	1,845	2,021	2,636	3,075	3,515	4,394
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	21,775	36,292	54,437	65,325	72,583	76,212	83,471	108,875	127,021	145,166	181,458
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	281	468	702	842	935	982	1,076	1,403	1,637	1,871	2,338
3	Yuma County Water Users' Association (14,701af M&I includes YAO's 489.95af conversion)[2,3]	Yuma County	6,212	10,353	15,529	18,635	20,706	21,741	23,811	31,058	36,235	41,411	51,764
3	University of Arizona	Yuma County	85	142	213	256	284	298	327	426	497	568	710
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	9	16	23	28	31	33	36	47	55	63	78
3	Unit B Irrigation & Drainage District[3]	Yuma County	1,323	2,204	3,307	3,968	4,409	4,629	5,070	6,613	7,715	8,818	11,022
1	PPR No. 15, Molina	Yuma County	25	42	62	75	83	87	95	125	145	166	208
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	35	58	87	104	116	122	133	174	203	232	290
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	341	568	852	1,023	1,136	1,193	1,307	1,704	1,988	2,273	2,841
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	480	800	1,199	1,439	1,599	1,679	1,839	2,399	2,799	3,198	3,998
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	13,340	22,234	33,351	40,021	44,467	46,691	51,137	66,701	77,818	88,935	111,168
1	PPR No. 7, Powers	Yuma County	49	81	122	147	163	171	187	244	285	326	407
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	30	51	76	91	102	107	117	152	178	203	254
1	PPR No. 10, Hulet (MVIDD)	Mohave County	46	76	114	137	152	160	175	228	266	305	381
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	44	74	111	133	148	155	170	222	259	296	370
1	PPR No. 12, Miller (MVIDD)	Mohave County	10	17	25	30	34	36	39	51	59	68	85
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	34	57	86	103	114	120	131	171	200	228	286
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	46	76	114	137	152	160	175	228	266	305	381
1	PPR No. 18, Swan (MVIDD)	Mohave County	41	68	102	122	135	142	156	203	237	271	338
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	3	5	8	10	11	12	13	16	19	22	27
-	-	**Subtotal**	**64,276**	**107,127**	**160,690**	**192,829**	**214,254**	**224,967**	**246,392**	**321,381**	**374,944**	**428,508**	**535,635**
California			-	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	392	653	979	1,175	1,305	1,371	1,501	1,958	2,285	2,611	3,264
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	25,848	43,080	64,620	77,544	86,160	90,468	99,084	129,240	150,780	172,320	215,400
3	Imperial Irrigation District (IID) (3a)	Imperial County	39,164	65,273	97,909	117,491	130,545	137,073	150,127	195,818	228,454	261,090	326,363
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	571	952	1,428	1,714	1,904	2,000	2,190	2,857	3,333	3,809	4,761

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	28,854	48,090	72,135	86,562	96,180	100,989	110,607	144,270	168,315	192,360	240,450
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	9	15	23	27	30	32	35	45	53	60	75
PPR	PPR No. 41, Chagnon	San Bernardino	6	10	15	18	20	21	23	30	35	40	50
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	5	8	12	14	16	17	18	24	28	32	40
PPR	PPR No. 34, Milpitas	Imperial County	5	9	14	16	18	19	21	27	32	36	45
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	1,529	2,548	3,822	4,586	5,096	5,351	5,860	7,644	8,918	10,192	12,740
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	203,651	339,418	509,126	610,952	678,835	712,777	780,661	1,018,253	1,187,962	1,357,671	1,697,088
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	7,402	12,337	18,506	22,207	24,674	25,908	28,376	37,012	43,180	49,349	61,686
PPR	PPR No. 42, Lawrence	Imperial County	6	10	15	18	20	21	23	30	35	40	50
PPR	PPR No. 37, Milpitas	Imperial County	3	6	9	10	12	12	13	17	20	23	29
PPR	PPR No. 33, Morgan	Imperial County	8	13	19	23	25	26	29	38	44	50	63
PPR	PPR No. 35, Simons	San Bernardino	3	5	8	9	10	11	12	15	18	20	25
-	-	**Subtotal**	**307,455**	**512,426**	**768,639**	**922,366**	**1,024,851**	**1,076,094**	**1,178,579**	**1,537,277**	**1,793,490**	**2,049,703**	**2,562,129**
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**371,732**	**619,553**	**929,329**	**1,115,195**	**1,239,105**	**1,301,061**	**1,424,971**	**1,858,658**	**2,168,434**	**2,478,211**	**3,097,763**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	917	1,528	2,292	2,750	3,056	3,209	3,514	4,584	5,348	6,112	7,640
-	Mohave County	-	1,734	2,890	4,335	5,202	5,781	6,070	6,648	8,671	10,116	11,561	14,451
-	Yuma County	-	61,625	102,709	154,063	184,876	205,417	215,688	236,230	308,126	359,480	410,835	513,543
_	**Subtotal Arizona Irrigation**	-	**64,276**	**107,127**	**160,690**	**192,829**	**214,254**	**224,967**	**246,392**	**321,381**	**374,944**	**428,508**	**535,635**
_	**California**	-	-	-	-	-	-	-	-	-	-	-	-
_	Riverside County	-	44,368	73,946	110,919	133,103	147,893	155,287	170,076	221,839	258,812	295,785	369,731
_	Imperial County	-	263,074	438,456	657,685	789,222	876,913	920,758	1,008,450	1,315,369	1,534,597	1,753,826	2,192,282
_	San Bernardino	-	14	23	35	42	46	48	53	69	81	92	115
_	**Subtotal California Irrigation**	-	**307,455**	**512,426**	**768,639**	**922,366**	**1,024,851**	**1,076,094**	**1,178,579**	**1,537,277**	**1,793,490**	**2,049,703**	**2,562,129**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
_	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
_	None	-	0	0	0	0	0	0	0	0	0	0	0

Disclaimer: These modeling results for the pro rata (w/o Tribal Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Table C-52
Pro Rata Without Tribal Shortage Alternative Distribution Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	229	382	573	687	764	802	878	1,146	1,337	1,528	1,909
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	1,496	2,493	3,739	4,487	4,985	5,235	5,733	7,478	8,724	9,971	12,463
CAP NIA-B	Carefree Water Company	Maricopa County	9	15	23	28	31	32	35	46	54	61	77
CAP NIA-B	Cave Creek	Maricopa County	32	53	79	95	106	111	122	159	185	212	265
CAP NIA-B	El Mirage	Maricopa County	108	181	271	325	361	379	416	542	632	723	903
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	265	441	661	794	882	926	1,014	1,323	1,543	1,764	2,205
CAP NIA-B	Freeport	Pima County	467	778	1,167	1,401	1,557	1,634	1,790	2,335	2,724	3,113	3,891
CAP NIA-B	Gilbert	Maricopa County	151	251	377	452	502	527	578	753	879	1,004	1,256
CAP NIA-B	Marana	Pima County	42	71	106	127	141	148	162	212	247	282	353
CAP NIA-B	Queen Creek	Maricopa County	342	570	856	1,027	1,141	1,198	1,312	1,711	1,997	2,282	2,852
CAP NIA-B	Resolution Copper	Maricopa County	184	307	460	552	614	644	706	920	1,074	1,227	1,534
CAP NIA-B	Rosemont Copper	Pima County	92	154	231	277	308	324	354	462	539	616	770
CAP NIA-B	SRP	Maricopa County	178	296	444	533	592	622	681	888	1,036	1,184	1,480
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	67	112	168	202	224	235	258	336	392	448	560
CAP NIA-A	Phoenix	Maricopa County	3,066	5,110	7,665	9,198	10,220	10,731	11,753	15,330	17,885	20,440	25,550
CAP NIA-A	Chandler	Maricopa County	323	538	807	968	1,076	1,130	1,237	1,614	1,883	2,151	2,689
CAP NIA-A	Gilbert	Maricopa County	126	211	316	379	421	442	485	632	737	843	1,053
CAP NIA-A	Glendale	Maricopa County	56	93	140	168	187	196	215	280	327	374	467
CAP NIA-A	Mesa	Maricopa County	457	761	1,141	1,370	1,522	1,598	1,750	2,283	2,663	3,044	3,804
CAP NIA-A	Scottsdale	Maricopa County	272	453	680	816	906	952	1,042	1,359	1,586	1,813	2,266

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Tempe	Maricopa County	2	3	5	6	6	7	7	9	11	13	16
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	41	69	103	123	137	144	158	206	240	274	343
CAP M&I	ASARCO	Pima County	1,727	2,879	4,318	5,181	5,757	6,045	6,621	8,636	10,075	11,514	14,393
CAP M&I	Avondale	Maricopa County	445	742	1,114	1,336	1,485	1,559	1,707	2,227	2,598	2,970	3,712
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	2,317	3,862	5,793	6,952	7,724	8,111	8,883	11,586	13,518	15,449	19,311
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	731	1,218	1,827	2,192	2,436	2,557	2,801	3,653	4,262	4,871	6,089
CAP M&I	Arizona Water Company, Coolidge	Pinal County	164	274	411	493	548	576	631	822	960	1,097	1,371
CAP M&I	Arizona Water Company, Superstition	Pinal County	517	862	1,292	1,551	1,723	1,809	1,981	2,585	3,015	3,446	4,308
CAP M&I	Arizona Water Company, White Tank	Maricopa County	80	133	199	239	265	279	305	398	464	531	663
CAP M&I	Buckeye	Maricopa County	6	9	14	17	19	20	21	28	33	37	47
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	528	881	1,321	1,585	1,762	1,850	2,026	2,642	3,083	3,523	4,404
CAP M&I	Carefree Water Company	Maricopa County	138	230	345	414	460	483	529	690	805	920	1,150
CAP M&I	Cave Creek	Maricopa County	183	305	458	550	611	641	702	916	1,069	1,222	1,527
CAP M&I	Chandler	Maricopa County	712	1,186	1,779	2,135	2,372	2,491	2,728	3,559	4,152	4,745	5,931
CAP M&I	Chaparral City Water Company	Maricopa County	733	1,221	1,832	2,198	2,442	2,564	2,809	3,664	4,274	4,885	6,106
CAP M&I	Circle City	Maricopa County	323	539	808	970	1,078	1,132	1,240	1,617	1,886	2,156	2,695
CAP M&I	El Mirage	Maricopa County	42	70	104	125	139	146	160	209	244	279	348
CAP M&I	Eloy	Pinal County	179	298	446	536	595	625	684	893	1,042	1,190	1,488
CAP M&I	EPCOR, Agua Fria	Maricopa County	912	1,521	2,281	2,737	3,041	3,193	3,497	4,562	5,322	6,082	7,603
CAP M&I	EPCOR, Paradise Valley	Maricopa County	266	443	664	797	886	930	1,019	1,329	1,550	1,772	2,214
CAP M&I	EPCOR, Sun City	Maricopa County	345	574	861	1,034	1,148	1,206	1,321	1,723	2,010	2,297	2,871
CAP M&I	EPCOR, Sun City West	Maricopa County	195	325	488	585	650	683	748	975	1,138	1,301	1,626
CAP M&I	Florence	Pinal County	168	281	421	505	561	590	646	842	983	1,123	1,404
CAP M&I	Freeport-Miami	Gila County	239	398	597	717	797	836	916	1,195	1,394	1,593	1,992

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	235	391	587	704	782	822	900	1,174	1,369	1,565	1,956
CAP M&I	Gilbert	Maricopa County	595	992	1,488	1,785	1,983	2,083	2,281	2,975	3,471	3,967	4,959
CAP M&I	Glendale	Maricopa County	1,418	2,363	3,544	4,253	4,725	4,961	5,434	7,088	8,269	9,450	11,813
CAP M&I	Goodyear	Maricopa County	883	1,472	2,209	2,650	2,945	3,092	3,387	4,417	5,154	5,890	7,362
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	5	9	13	16	18	18	20	26	31	35	44
CAP M&I	Green Valley Community Water Company	Pima County	235	392	588	705	784	823	901	1,175	1,371	1,567	1,959
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	156	260	391	469	521	547	599	781	912	1,042	1,302
CAP M&I	Marana	Pima County	192	320	480	576	640	672	736	961	1,121	1,281	1,601
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	55	91	137	164	182	191	210	273	319	365	456
CAP M&I	Mesa	Maricopa County	3,578	5,963	8,945	10,734	11,926	12,522	13,715	17,889	20,871	23,852	29,815
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	1,107	1,845	2,767	3,321	3,690	3,874	4,243	5,535	6,457	7,380	9,225
CAP M&I	Oro Valley	Pima County	848	1,413	2,119	2,543	2,825	2,966	3,249	4,238	4,944	5,650	7,063
CAP M&I	Peoria	Maricopa County	2,231	3,718	5,576	6,692	7,435	7,807	8,550	11,153	13,011	14,870	18,588
CAP M&I	Phoenix	Maricopa County	10,371	17,285	25,928	31,114	34,571	36,299	39,756	51,856	60,499	69,142	86,427
CAP M&I	Pine	Gila County	13	22	33	40	44	46	51	66	77	88	110
CAP M&I	Queen Creek	Maricopa County	41	68	102	122	136	142	156	204	237	271	339
CAP M&I	Rio Verde Utilities	Maricopa County	67	111	167	200	223	234	256	334	390	445	557
CAP M&I	San Tan Irrigation District	Maricopa County	19	32	49	58	65	68	74	97	113	129	162
CAP M&I	Scottsdale	Maricopa County	4,343	7,239	10,858	13,030	14,478	15,201	16,649	21,716	25,336	28,955	36,194
CAP M&I	Spanish Trail Water Company	Pima County	250	416	624	749	833	874	957	1,249	1,457	1,665	2,081
CAP M&I	Surprise	Maricopa County	843	1,405	2,107	2,529	2,810	2,950	3,231	4,215	4,917	5,619	7,024
CAP M&I	Tempe	Maricopa County	355	591	887	1,065	1,183	1,242	1,360	1,774	2,070	2,366	2,957
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	6	10	15	18	19	20	22	29	34	39	49
CAP M&I	Tucson	Pima County	11,859	19,765	29,647	35,576	39,529	41,506	45,459	59,294	69,176	79,058	98,823

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Vail Water Company	Pima County	153	255	382	458	509	535	585	764	891	1,018	1,273
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	240	400	600	720	800	840	920	1,200	1,400	1,600	2,001
4(i)	Arizona State Land Department	Yuma County	77	128	192	231	256	269	295	384	449	513	641
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	5	8	11	14	15	16	18	23	27	31	38
4(i)	B&F Investment, LLC	La Paz County	3	5	8	10	11	11	12	16	19	22	27
4(i)	Bullhead City	Mohave County	786	1,310	1,966	2,359	2,621	2,752	3,014	3,931	4,587	5,242	6,552
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	111	184	276	332	369	387	424	553	645	737	921
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	362	603	905	1,086	1,206	1,267	1,387	1,809	2,111	2,412	3,016
4(i)	Bureau of Land Management	La Paz County	314	523	785	942	1,047	1,099	1,204	1,570	1,832	2,094	2,617
4(i)	Crystal Beach Water Conservation District	Mohave County	7	11	17	20	22	24	26	34	39	45	56
4(i)	Ehrenburg Improvement District	La Paz County	36	60	91	109	121	127	139	181	212	242	302
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	97	161	242	291	323	339	371	484	565	646	807
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	3	5	7	8	9	10	11	14	16	19	23
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	0	0	0	0	0	1	1
4(i)	Gold Dome Mining Corporation	Yuma County	1	1	1	2	2	2	2	3	3	4	5
4(i)	Golden Shores Water Conservation District	Mohave County	105	175	262	315	350	367	402	525	612	700	875
4(i)	GSC Farm, LLC	La Paz County	4	7	10	12	13	14	15	20	23	26	33
4(i)	Hillcrest Water Company	La Paz County	4	7	11	13	14	15	16	21	25	29	36
4(i)	Lake Havasu City	Mohave County	932	1,553	2,330	2,796	3,107	3,262	3,573	4,660	5,437	6,214	7,767
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	104	173	260	312	346	364	398	519	606	693	866
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	352	587	880	1,056	1,174	1,232	1,350	1,760	2,054	2,347	2,934
4(i)	La Paz County	La Paz County	27	46	69	82	91	96	105	137	160	183	228
4(i)	Martinez Lake Cabin Sites	Yuma County	1	2	3	3	4	4	4	6	7	8	10
4(i)	McAlister Family Trust	Mohave County	2	4	5	6	7	8	8	11	13	14	18
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	53	88	132	159	176	185	203	264	308	352	441
4(i)	Mohave Water Conservation District	Mohave County	94	157	236	283	315	331	362	472	551	630	787

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	157	262	394	472	525	551	604	787	918	1,050	1,312
4(i)	Parker, Town of[1]	La Paz County	34	56	85	102	113	119	130	169	198	226	282
4(i)	Quartzsite, Town of	La Paz County	84	140	210	251	279	293	321	419	489	559	698
4(i)	Queen Creek, Town of	Maricopa County	159	265	398	478	531	557	610	796	929	1,062	1,327
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	0	0	0	0	0	1	1
4(i)	Shepard Water Company, Incorporated	Yuma County	3	4	6	8	8	9	10	13	15	17	21
4(i)	Somerton, City of	Yuma County	59	98	147	176	196	206	225	294	343	392	490
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	6	10	14	17	19	20	22	29	33	38	48
4(i)	TV Marble Canyon AZ, LLC	Coconino County	4	6	9	11	12	12	14	18	21	24	30
3	City of Yuma[1]	Yuma County	3,801	6,334	9,501	11,402	12,669	13,302	14,569	19,003	22,170	25,337	31,672
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	2	3	5	6	7	7	8	10	12	13	17
3	Kaman, Inc.	Yuma County	0	0	0	0	1	1	1	1	1	1	1
3	Department of the Navy, MCAS	Yuma County	235	392	587	705	783	822	901	1,175	1,371	1,567	1,958
3	City of Yuma (cemetery)	Yuma County	5	8	12	14	16	16	18	23	27	31	39
3	Yuma Mesa Fruit Growers' Association	Yuma County	1	2	3	4	4	4	5	6	7	8	10
3	Desert Lawn Memorial Park Association	Yuma County	11	18	27	32	36	38	41	54	63	72	90
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	335	558	838	1,005	1,117	1,173	1,284	1,675	1,955	2,234	2,792
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	530	883	1,324	1,589	1,765	1,854	2,030	2,648	3,090	3,531	4,414
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	235	392	587	705	783	822	901	1,175	1,371	1,567	1,958
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	216	360	540	649	721	757	829	1,081	1,261	1,441	1,802
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	392	653	979	1,175	1,305	1,371	1,501	1,958	2,285	2,611	3,264
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	8	13	20	23	26	27	30	39	46	52	65
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	8	13	20	23	26	27	30	39	46	52	65
3	Department of the Army - Yuma Proving Ground	Yuma County	88	147	221	265	295	310	339	442	516	590	737
3	Yuma Union High School District	Yuma County	12	19	29	35	39	41	44	58	68	77	97

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	19	32	49	58	65	68	75	97	113	130	162
2	Cibola National Wildlife Refuge	La Paz County	1,315	2,192	3,288	3,946	4,384	4,604	5,042	6,577	7,673	8,769	10,961
2	Lake Mead National Recreation Area	Mohave County	27	45	67	81	90	94	103	134	157	179	224
2	Bureau of Reclamation - Davis Dam	Mohave County	1	1	1	2	2	2	2	3	3	4	5
2	Imperial National Wildlife Refuge	La Paz County	1,802	3,003	4,504	5,405	6,005	6,305	6,906	9,008	10,509	12,010	15,013
2	Havasu Lake National Wildlife Refuge	Mohave County	2,929	4,882	7,323	8,788	9,765	10,253	11,229	14,647	17,088	19,529	24,411
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	19	31	47	56	62	65	71	93	109	124	155
1	PPR No. 20, Parker, City of	La Paz County	31	52	78	94	104	110	120	157	183	209	261
1	PPR No. 21, Yuma, City of	Yuma County	116	193	289	347	386	405	444	579	675	772	965
-	-	**Subtotal**	**75,173**	**125,289**	**187,933**	**225,520**	**250,578**	**263,106**	**288,164**	**375,866**	**438,511**	**501,155**	**626,444**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	30,391	50,652	75,978	91,173	101,304	106,369	116,499	151,955	177,281	202,607	253,259
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	0

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 30, Stephenson	San Bernardino	12	20	30	36	40	42	46	60	70	80	100
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 38, Andrade	San Bernardino	3	6	8	10	11	12	13	17	19	22	28
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	3	5	8	9	10	11	12	15	18	20	25
PPR	PPR No. 39, Reynolds	San Bernardino	2	3	5	5	6	6	7	9	11	12	15
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	21	36	53	64	71	75	82	107	125	143	178
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	6	10	15	18	20	21	23	30	35	40	50

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 43, City of Needles	San Bernardino	74	124	186	223	248	260	285	372	434	496	620
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	39	65	98	117	130	137	150	196	228	261	326
-	-	**Subtotal**	**30,554**	**50,923**	**76,385**	**91,662**	**101,846**	**106,938**	**117,123**	**152,769**	**178,231**	**203,692**	**254,615**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	7,262	12,104	18,156	21,787	24,207	25,418	27,839	36,311	42,363	48,415	60,519
8	Big Bend Water District	Clark	384	640	960	1,151	1,279	1,343	1,471	1,919	2,239	2,559	3,198
8	Robert B. Griffith Project	Clark	12,382	20,637	30,955	37,146	41,273	43,337	47,464	61,910	72,228	82,546	103,183
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	1	1	1	1	1	2	2	2	3	3
7	Bureau of Reclamation (includes Sportsman Park)	Clark	12	19	29	35	38	40	44	58	67	77	96
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	2	3	5	6	7	7	8	10	11	13	16
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	163	272	407	489	543	570	625	815	950	1,086	1,358
6	Las Vegas Valley Water District	Clark	628	1,046	1,569	1,883	2,092	2,196	2,406	3,138	3,661	4,184	5,229
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	38	63	94	113	126	132	145	189	220	252	315
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	334	557	836	1,003	1,114	1,170	1,282	1,672	1,950	2,229	2,786
4	City of Henderson	Clark	647	1,078	1,617	1,940	2,156	2,263	2,479	3,234	3,772	4,311	5,389
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	609	1,015	1,522	1,827	2,030	2,131	2,334	3,045	3,552	4,059	5,074
3	Boulder City	Clark	239	399	598	718	798	838	917	1,197	1,396	1,596	1,994
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	117	196	294	352	392	411	450	587	685	783	979
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	23	39	59	70	78	82	90	117	137	157	196
-	-	**Subtotal**	**22,840**	**38,067**	**57,101**	**68,521**	**76,135**	**79,941**	**87,555**	**114,202**	**133,235**	**152,269**	**190,336**
-	-	**Total**	**128,567**	**214,279**	**321,419**	**385,702**	**428,558**	**449,986**	**492,842**	**642,837**	**749,977**	**857,117**	**1,071,396**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	4	6	9	11	12	12	14	18	21	24	30
-	Gila County	-	252	420	631	757	841	883	967	1,261	1,471	1,682	2,102
-	La Paz County	-	3,680	6,133	9,199	11,039	12,265	12,878	14,105	18,398	21,464	24,530	30,663
-	Maricopa County	-	40,988	68,314	102,471	122,965	136,627	143,459	157,122	204,941	239,098	273,255	341,569
-	Mohave County	-	6,124	10,206	15,309	18,371	20,412	21,433	23,474	30,618	35,721	40,824	51,030
-	Pima County	-	17,363	28,938	43,407	52,089	57,876	60,770	66,558	86,814	101,283	115,752	144,690
-	Pinal County	-	2,331	3,885	5,827	6,993	7,770	8,158	8,935	11,654	13,597	15,539	19,424
-	Yuma County	-	4,432	7,387	11,081	13,297	14,775	15,513	16,991	22,162	25,856	29,549	36,937
-	**Subtotal Arizona Domestic**	-	**75,173**	**125,289**	**187,933**	**225,520**	**250,578**	**263,106**	**288,164**	**375,866**	**438,511**	**501,155**	**626,444**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	30,391	50,652	75,978	91,173	101,304	106,369	116,499	151,955	177,281	202,607	253,259
-	Imperial County	-	47	78	116	140	155	163	178	233	271	310	388
-	Riverside County	-	0	0	1	1	1	1	1	1	1	2	2
-	San Bernardino	-	116	193	290	348	387	406	445	580	677	773	967
-	**Subtotal California Domestic**	-	**30,554**	**50,923**	**76,385**	**91,662**	**101,846**	**106,938**	**117,123**	**152,769**	**178,231**	**203,692**	**254,615**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	22,840	38,067	57,101	68,521	76,135	79,941	87,555	114,202	133,235	152,269	190,336
-	**Subtotal Nevada Domestic**	-	**22,840**	**38,067**	**57,101**	**68,521**	**76,135**	**79,941**	**87,555**	**114,202**	**133,235**	**152,269**	**190,336**

Disclaimer: These modeling results for the pro rata (w/o Tribal Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]This user also holds a PPR entitlement.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

C.11 Pro Rata Without Tribal PPR Shortage Alternative Distribution Model

The Pro Rata Without Tribal PPR Shortage Alternative Distribution Model is an adaptation of the Pro Rata Alternative Distribution Model that represents a distribution of shortages to all entitlements except tribal PPRs. It simulates shortages and distributes water on a proportional basis (i.e., at the same percentage reduction from each entitlement) across all lower Colorado River water entitlements that are not tribal PPRs, and assumes all tribal PPR entitlements are fully satisfied and are never shorted. This Alternative Distribution Model reflects a modeling commitment to display a distribution of water during shortage that does not short certain tribal entitlements. It is not an interpretation of law, contracts, or a legal position.

The Excel workbook contains formulas extending into deep shortage levels as a modeling exercise relating to potential capacity constraints on Lake Mead releases, and as a basis for comparison with other distributions of shortage. This deeper shortage level modeling does not represent an effect of the Federal action(s) described in this EIS, and this modeling is for informational purposes only.

C.11.1 Distribution Among Water Users

Assumptions for this Alternative Distribution Model are the same as for the Pro Rata Without Tribal Shortage Alternative Distribution Model except as described below. The entitlements listed in the following **Table C-53** were removed from the distribution of shortage in this Alternative Distribution Model.

Table C-53
PPRs Not Shorted Under this Alternative Distribution Model

Entitlement Holders	CU Equivalent (af)*	Diversion (af)	PPR No.	Date	Type of Use
Cocopah Indian Reservation	5,146	7,681	1	1917	Tribal
United States (Cocopah Indian Tribe)	764	1,140	8	1915	Tribal
Chemehuevi Indian Reservation	6,124	11,340	22	1907	Tribal
Fort Mojave Indian Reservation	40,806	75,566	3	1890	Tribal
Fort Mojave Indian Reservation	15,103	27,969	3	1890	Tribal
Fort Mojave Indian Reservation	9,029	16,720	25	1890	Tribal
Fort Mojave Indian Reservation	8,398	12,534	81	1890	Tribal
Fort Yuma Indian Reservation	36,524	71,616	23	1884	Tribal
Fort Yuma Indian Reservation	4,001	6,350	3a	1884	Tribal
Colorado River Indian Reservation	3,399	5,860	24	1876	Tribal
Colorado River Indian Reservation	27,033	51,986	2	1874	Tribal
Colorado River Indian Reservation	23,340	40,241	24	1874	Tribal

Entitlement Holders	CU Equivalent (af)*	Diversion (af)	PPR No.	Date	Type of Use
Colorado River Indian Reservation	131,048	252,016	2	1873	Tribal
Colorado River Indian Reservation	6,232	10,745	24	1873	Tribal
Colorado River Indian Reservation	186,368	358,400	2	1865	Tribal

*Calculated consumptive use equivalents. Historical Decree Accounting data were used to estimate average CU/Diversion ratios as part of development of the CRSS hydrologic modeling dataset for this EIS. For purposes of modeling, these values are assumed to be generally representative of return flow conditions for the specified users, and match CRSS inputs. Those ratios were used to estimate the consumptive use equivalent of diversion entitlements. In CA, miscellaneous PPRs were assumed to have a CU/Div ratio of .64. For IID, consumptive use was assumed to equal diversion since the CU/diversion ratio based on average historical efficiency was 0.996. In AZ, with limited supporting data about miscellaneous PPRs, they were assumed to be fully consumptive. Where an entitlement was quantified on the basis of CU by the Consolidated Decree, those values are used.

A non-shorted component is set aside for Mexico in proportion to the non-shorted tribal PPR entitlements in the U.S.; in this model, 6.71 percent of 1.5 mafy, or 100,663 afy. Entitlements subject to shortage in this Alternative Distribution Model are summarized in the following **Table C-54**.

Table C-54
Non-Tribal Entitlements Subject to Shortage Under this Alternative Distribution Model

Arizona, California, Nevada, and Mexico Summary	CU Equivalent (afy)
Arizona Total	2,412,642
California Total	4,315,353
Nevada Total	291,602
Mexico Total	1,399,337
Total	**8,418,934**

C.11.2 Pro Rata Without PPR Tribal Shortage Alternative Distribution Model Results

The tables in this section present the results of the Pro Rata Without PPR Tribal Shortage Alternative Distribution Model over a range of total shortages to the Lower Basin including Mexico.

Table C-55, the Regional Summary, summarizes the shortage attributed to each priority within the Lower Division States and reflects shortage attributed to Mexico.

Table C-56, the Tribal Summary, presents the shortage impacts on tribes.

Table C-57, the Irrigation Summary, presents the shortage impacts on irrigators.

Table C-58, the Domestic Summary, presents the shortage impacts on domestic users.

Table C-55
Pro Rata Without PPR Tribal Shortage Alternative Distribution Model Regional Summary

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-	-	600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	5th, 6th, and CAP Agricultural and Other Excess[1]	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced	Fully Reduced
-	4th Priority ii (CAP) at the Point of Diversion[2]	-	-	-	-	-	-	-	-	-	-	-
-	NIA Priority	20,460	34,100	51,150	61,380	68,200	71,610	78,430	102,300	119,350	136,400	170,500
-	M&I Priority	47,804	79,673	119,510	143,412	159,347	167,314	183,249	239,020	278,856	318,693	398,366
-	Indian Priority	25,673	42,788	64,183	77,019	85,577	89,856	98,413	128,365	149,759	171,154	213,942
-	4th Priority i (Mainstream)	7,765	12,942	19,413	23,296	25,884	27,178	29,767	38,826	45,297	51,768	64,710
-	2nd & 3rd Priorities	56,876	94,793	142,190	170,628	189,587	199,066	218,025	284,380	331,777	379,173	473,967
-	1st Priority (Present Perfected Rights)	13,366	22,276	33,414	40,097	44,553	46,780	51,236	66,829	77,967	89,105	111,382
-	**Subtotal**	**171,944**	**286,573**	**429,860**	**515,832**	**573,147**	**601,804**	**659,119**	**859,720**	**1,003,007**	**1,146,293**	**1,432,867**
California	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	4th Priority (MWD)	27,652	46,087	69,130	82,956	92,174	96,782	106,000	138,260	161,304	184,347	230,434
-	3rd Priority (IID, CVWD, PVID)	59,509	99,181	148,772	178,526	198,362	208,281	228,117	297,544	347,134	396,725	495,906
-	2nd Priority (Yuma Project Reservation Division)	520	866	1,300	1,559	1,733	1,819	1,993	2,599	3,032	3,466	4,332
-	1st Priority (PVID)	26,254	43,756	65,634	78,761	87,512	91,887	100,639	131,268	153,146	175,024	218,779
-	Present Perfected Rights (PPRs)	193,612	322,687	484,030	580,836	645,374	677,642	742,180	968,060	1,129,404	1,290,747	1,613,434
-	**Subtotal**	**307,546**	**512,577**	**768,866**	**922,639**	**1,025,154**	**1,076,412**	**1,178,927**	**1,537,731**	**1,794,020**	**2,050,308**	**2,562,885**
Nevada	**Priority**	-	-	-	-	-	-	-	-	-	-	-
-	8th Priority (SNWA - Balance & Unused)	6,608	11,013	16,519	19,823	22,026	23,127	25,330	33,039	38,545	44,051	55,064
-	8th Priority (SNWA & Big Bend)	11,615	19,359	29,038	34,846	38,717	40,653	44,525	58,076	67,756	77,435	96,794
-	7th Priority (Boy Scouts, USBR, NV Dept of Wildlife)	161	268	402	483	536	563	617	804	938	1,072	1,341
-	6th Priority (Las Vegas Valley Water District)	571	952	1,427	1,713	1,903	1,998	2,189	2,855	3,331	3,806	4,758
-	5th Priority (PABCO)	34	57	86	103	115	120	132	172	201	229	287
-	4th Priority (Henderson & Basic)	1,447	2,411	3,617	4,340	4,822	5,063	5,545	7,233	8,439	9,644	12,055
-	3rd Priority (Boulder City)	218	363	544	653	726	762	835	1,089	1,270	1,452	1,815

Summary of Shortage Impacts by State and Priority		Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-	**-**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**
-	2nd Priority (Lake Mead National Rec Area)	107	178	267	321	356	374	410	535	624	713	891
-	1st Priority (PPR: LMNRA)	21	36	53	64	71	75	82	107	125	143	178
-	**Subtotal**	**20,782**	**34,636**	**51,955**	**62,346**	**69,273**	**72,737**	**79,664**	**103,909**	**121,228**	**138,546**	**173,182**
-	**Lower Division States Subtotal**	**500,272**	**833,787**	**1,250,680**	**1,500,816**	**1,667,574**	**1,750,952**	**1,917,710**	**2,501,361**	**2,918,254**	**3,335,148**	**4,168,934**
Mexico	**Mexico Subtotal**	**99,728**	**166,213**	**249,320**	**299,184**	**332,426**	**349,048**	**382,290**	**498,639**	**581,746**	**664,852**	**831,066**
-	**Total**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,500,000**	**4,000,000**	**5,000,000**

Disclaimer: These modeling results for the pro rata (w/o Tribal PPR Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
[1]Agricultural and Other CAP Excess contracts do not confer a Colorado River water entitlement and cannot be exercised under any of the scenarios modeled here
[2]The CAP priority system is not maintained in the pro rata distribution. CAP contractors and subcontractors are shorted pro rata with non-CAP water users; therefore, there is not an Available CAP Supply calculated for the pro rata alternative distribution model, or a shortage volume given for CAP as a whole.

Table C-56
Pro Rata Without PPR Tribal Shortage Alternative Distribution Model Tribal Summary

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	1,780	2,966	4,449	5,339	5,932	6,229	6,822	8,898	10,381	11,864	14,830
CAP NIA-A Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)	Pima County	2,110	3,517	5,276	6,331	7,034	7,386	8,089	10,551	12,310	14,068	17,585
CAP NIA-A Priority	Gila River Indian Community	Maricopa and Pinal County	9,025	15,041	22,562	27,074	30,082	31,586	34,595	45,123	52,644	60,164	75,205
CAP NIA-A Priority	Hualapai Tribe	Coconino and Mohave County	299	499	748	898	998	1,048	1,147	1,497	1,746	1,996	2,494
CAP Indian Priority	Gila River Indian Community[1]	Maricopa and Pinal County	14,308	23,846	35,769	42,923	47,692	50,077	54,846	71,539	83,462	95,385	119,231
CAP Indian Priority	Tohono O'odham Nation (Schuk Toak & San Xavier Districts)[1]	Pima County	2,829	4,714	7,072	8,486	9,429	9,900	10,843	14,143	16,500	18,857	23,572
CAP Indian Priority	White Mountain Apache Tribe	Apache, Gila, and Navajo	91	152	228	273	304	319	349	456	532	608	760
CAP Indian Priority	Ak-Chin Indian Community[1]	Pinal County	4,363	7,271	10,907	13,088	14,542	15,269	16,724	21,813	25,449	29,084	36,356
CAP Indian Priority	Fort McDowell Yavapai Nation	Maricopa County	1,364	2,274	3,411	4,093	4,548	4,775	5,230	6,822	7,959	9,096	11,370
CAP Indian Priority	Pascua Yaqui Tribe	Pima County	37	62	94	112	125	131	143	187	218	249	312
CAP Indian Priority	San Carlos Apache Tribe	Gila County	950	1,584	2,376	2,851	3,168	3,326	3,643	4,752	5,544	6,336	7,920
CAP Indian Priority	Salt River Pima-Maricopa Indian Community	Maricopa County	995	1,659	2,488	2,986	3,318	3,483	3,815	4,976	5,806	6,635	8,294
CAP Indian Priority	Tohono O'odham Nation Sif Oidak District	Pinal County	599	998	1,497	1,796	1,996	2,095	2,295	2,993	3,492	3,991	4,989
CAP Indian Priority	Tonto Apache Tribe	Gila County	10	16	24	29	32	34	37	48	56	64	80
CAP Indian Priority	Yavapai Apache Nation	Gila County	90	150	224	269	299	314	344	449	524	599	748
CAP M&I Priority	San Carlos Apache Tribe	Gila County	1,358	2,263	3,395	4,073	4,526	4,752	5,205	6,789	7,921	9,052	11,315
4(i)	Hopi Tribe[1]	La Paz County	216	361	541	649	722	758	830	1,082	1,263	1,443	1,804
4(i)	Cocopah Indian Reservation	Yuma County	97	161	242	290	322	339	371	484	564	645	806
4(i)	Water Reserved by the Secretary for a Navajo-Hopi Settlement	Apache, Navajo, Coconino	249	416	624	748	831	873	956	1,247	1,455	1,663	2,079
4(i)	Unallocated 4th Priority Mainstream Water[2]	Yuma County	729	1,215	1,823	2,187	2,430	2,552	2,795	3,645	4,253	4,860	6,076

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Ak-Chin Indian Community[1]	Pinal County	3,563	5,939	8,908	10,690	11,878	12,472	13,660	17,817	20,786	23,756	29,695
1	PPR No. 1, Cocopah Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 8, United States (Cocopah Indian Tribe)[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3, Fort Mojave Indian Reservation[1]	Mohave County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 3a, Fort Yuma Indian Reservation[1]	Yuma County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
1	PPR No. 2, Colorado River Indian Reservation[1]	La Paz County	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**45,062**	**75,104**	**112,656**	**135,187**	**150,208**	**157,719**	**172,739**	**225,312**	**262,864**	**300,416**	**375,520**
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
PPR	PPR No. 22, Chemehuevi Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 25, Fort Mojave Indian Reservation[1]	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 23, Fort Yuma Indian Reservation[1]	Imperial	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 24, Colorado River Indian Reservation[1]	San Bernardino, Riverside	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
1	PPR No. 81, Fort Mojave Indian Reservation[1]	Clark	0	0	0	0	0	0	0	0	0	0	0
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**45,062**	**75,104**	**112,656**	**135,187**	**150,208**	**157,719**	**172,739**	**225,312**	**262,864**	**300,416**	**375,520**

Summary of Consumptive Use Impacts to Tribal Allocations			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Summary by County													
_	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
_	Coconino County	-	233	388	582	698	776	815	892	1,164	1,358	1,552	1,940
_	Gila County	-	3,031	5,052	7,578	9,093	10,104	10,609	11,619	15,156	17,682	20,208	25,260
_	La Paz County	-	216	361	541	649	722	758	830	1,082	1,263	1,443	1,804
_	Maricopa County	-	9,359	15,599	23,398	28,078	31,198	32,758	35,878	46,797	54,596	62,396	77,995
_	Mohave County	-	150	249	374	449	499	524	574	748	873	998	1,247
_	Pima County	-	4,976	8,294	12,441	14,929	16,588	17,417	19,076	24,881	29,028	33,175	41,469
_	Pinal County	-	24,857	41,429	62,143	74,572	82,858	87,001	95,287	124,287	145,001	165,716	207,145
_	Yuma County	-	826	1,376	2,065	2,477	2,753	2,890	3,166	4,129	4,817	5,505	6,882
_	Apache County	-	707	1,178	1,767	2,120	2,356	2,474	2,709	3,534	4,123	4,712	5,890
_	Navajo County	-	707	1,178	1,767	2,120	2,356	2,474	2,709	3,534	4,123	4,712	5,890
_	**Subtotal Arizona Tribal**	-	**45,062**	**75,104**	**112,656**	**135,187**	**150,208**	**157,719**	**172,739**	**225,312**	**262,864**	**300,416**	**375,520**
_	**California**	-	-	-	-	-	-	-	-	-	-	-	-
_	San Bernardino	-	0	0	0	0	0	0	0	0	0	0	0
_	Riverside	-	0	0	0	0	0	0	0	0	0	0	-
_	Imperial	-	0	0	0	0	0	0	0	0	0	0	0
_	**Subtotal California Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
_	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
_	Clark	-	0	0	0	0	0	0	0	0	0	0	0
_	**Subtotal Nevada Tribal**	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Disclaimer: These modeling results for the pro rata (w/o Tribal PPR Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis attributes shortage to the base allocation or entitlement according to its priority, representing an opportunity cost. The ultimate impacts, both financial and in terms of the lost productive value of water, are diverse according to their varied uses and compensation structures under a large body of exchanges, leases, and other Federal and non-Federal arrangements and commitments. The modeled distribution of shortage to the base allocation reflects how shortage affects the ability for allocations to be exercised, and water users will face decisions in administering agreements during a Shortage Condition; actual water orders received each year will affect shortage impacts.
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Denotes full or substantial use in tribal agricultural operations, which may or may not be impacted according to the terms of related agreements.
[2]Likely to include domestic, irrigation, and Tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

Table C-57
Pro Rata Without PPR Tribal Shortage Alternative Distribution Model Irrigation Summary

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4(i)	Arizona Game and Fish Commission	La Paz County	146	243	364	437	485	510	558	728	849	971	1,214
4(i)	Arizona State Land Department	Yuma County	301	502	753	904	1,005	1,055	1,155	1,507	1,758	2,009	2,511
4(i)	Beattie Farms, Southwest	Yuma County	51	86	129	154	171	180	197	257	300	343	428
4(i)	Bishop, Alfred F. and Erma Jean Family Trust	La Paz County	21	35	53	64	71	74	81	106	124	142	177
4(i)	Cathcart, Bruce Y. and Lora M. and James Y. and Maria E.	La Paz County	6	11	16	19	21	22	24	32	37	43	53
4(i)	Perricone Arizona Properties, LLC and Meyer Farms, LLC	Yuma County	97	162	243	292	324	340	373	486	567	649	811
4(i)	Cibola Sportsman's Club, Inc.	La Paz County	11	18	27	33	36	38	42	55	64	73	91
4(i)	Cibola Valley Irrigation and Drainage District[2]	La Paz County	377	628	941	1,130	1,255	1,318	1,444	1,883	2,197	2,511	3,138
4(i)	Curtis, Armon	Yuma County	14	23	35	42	46	49	53	69	81	93	116
4(i)	Gila Monster Farms, Inc.[3]	Yuma County	58	97	146	175	194	204	223	291	340	389	486
4(i)	Matador Farms, LLC	La Paz County	208	347	521	625	695	730	799	1,042	1,216	1,390	1,737
4(i)	JRJ Partners, L.L.C.	Yuma County	50	83	125	150	167	175	192	250	292	334	417
4(i)	Mohave Valley Irrigation and Drainage District[2,3]	Mohave County	1,349	2,249	3,373	4,048	4,498	4,722	5,172	6,746	7,871	8,995	11,244
4(i)	North Baja Pipeline, LLC[2]	La Paz County	22	37	56	67	74	78	85	111	130	148	185
4(i)	Ogram Boys Enterprises, Inc.	Yuma County	43	71	107	128	143	150	164	214	250	285	357
4(i)	Ott, Larry and Gina, and Lee C. and Candace M.	Yuma County	22	37	56	67	74	78	85	111	130	148	185
4(i)	Pasquinelli, Gary J. and Barbara J.	Yuma County	23	38	56	68	75	79	86	113	131	150	188
4(i)	Red River Land Company, LLC	La Paz County	15	25	38	46	51	53	58	76	89	101	127
4(i)	Phillips, Milton and Jean	Yuma County	4	7	11	13	14	15	16	21	25	29	36
4(i)	Western Water, LLC	La Paz County	28	46	69	83	92	96	106	138	161	184	229
3	Sturges, Harold	Yuma County	24	40	60	72	80	84	92	119	139	159	199
3	Sturges, Irma	Yuma County	27	46	69	82	91	96	105	137	160	183	229

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Yuma Mesa Irrigation & Drainage District (10.0 kaf M&I)[1]	Yuma County	10,086	16,810	25,214	30,257	33,619	35,300	38,662	50,429	58,834	67,238	84,048
3	Yuma Irrigation District (5.0 kaf M&I)[1]	Yuma County	4,795	7,991	11,987	14,384	15,983	16,782	18,380	23,974	27,969	31,965	39,956
3	North Gila Valley Irrigation District (2.5 kaf M&I)[1,3]	Yuma County	480	800	1,199	1,439	1,599	1,679	1,839	2,399	2,798	3,198	3,998
3	Wellton-Mohawk Irrigation and Drainage District (12.0 kaf M&I)[1]	Yuma County	19,812	33,021	49,531	59,437	66,042	69,344	75,948	99,062	115,573	132,083	165,104
3	Gila Monster Farms (formerly Sturges)[3]	Yuma County	255	426	638	766	851	894	979	1,277	1,489	1,702	2,128
3	Yuma County Water Users' Association (14,701 af M&I includes YAO's 489.95 af conversion)[2,3]	Yuma County	5,652	9,420	14,130	16,955	18,839	19,781	21,665	28,259	32,969	37,679	47,099
3	University of Arizona	Yuma County	78	129	194	233	259	271	297	388	452	517	646
3	Camille Allec, Jr. (Formerly Yuma Mesa Grapefruit Company)	Yuma County	9	14	21	26	29	30	33	43	50	57	71
3	Unit B Irrigation & Drainage District[3]	Yuma County	1,203	2,006	3,009	3,610	4,011	4,212	4,613	6,017	7,020	8,023	10,029
1	PPR No. 15, Molina	Yuma County	23	38	57	68	76	79	87	113	132	151	189
1	PPR No. 16, Sturges (Gila Monster Farms, Inc.)	Yuma County	32	53	79	95	106	111	121	158	185	211	264
1	PPR No. 5, Yuma Auxiliary Project, Unit B	Yuma County	310	517	775	930	1,034	1,086	1,189	1,551	1,809	2,068	2,585
1	PPR No. 6, North Gila Valley Unit, Yuma Mesa Division, Gila Project	Yuma County	437	728	1,091	1,310	1,455	1,528	1,673	2,183	2,546	2,910	3,638
1	PPR No. 4, Valley Division, Yuma Project (Yuma County Water Users' Association)	Yuma County	12,138	20,230	30,345	36,414	40,460	42,483	46,529	60,690	70,805	80,920	101,149
1	PPR No. 7, Powers	Yuma County	44	74	111	133	148	156	170	222	259	296	371
1	PPR No. 17, Zozaya (MVIDD)	Mohave County	28	46	69	83	92	97	106	139	162	185	231
1	PPR No. 10, Hulet (MVIDD)	Mohave County	42	69	104	125	139	145	159	208	242	277	346
1	PPR No. 11, Hurschler (First American Title Insurance Agency of Mohave, Inc.) (MVIDD)	Mohave County	40	67	101	121	135	141	155	202	236	269	337
1	PPR No. 12, Miller (MVIDD)	Mohave County	9	15	23	28	31	32	35	46	54	62	77
1	PPR No. 13, McKellips and Granite Reef Farms (MVIDD)	Mohave County	31	52	78	94	104	109	119	156	182	208	260
1	PPR No. 14, Sherrill & Lafollette (MVIDD)	Mohave County	42	69	104	125	139	145	159	208	242	277	346
1	PPR No. 18, Swan (MVIDD)	Mohave County	37	62	92	111	123	129	142	185	216	246	308
1	PPR No. 19, Phillips, Milton and Jean	Yuma County	3	5	7	9	10	10	11	15	17	20	25
-	-	**Subtotal**	**58,483**	**97,472**	**146,208**	**175,450**	**194,944**	**204,692**	**224,186**	**292,416**	**341,153**	**389,889**	**487,361**

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
3	Palo Verde Irrigation District (3b) - Lower Palo Verde Mesa Lands	Riverside County	356	594	891	1,069	1,188	1,247	1,366	1,782	2,079	2,376	2,969
3	Coachella Valley Water District (CVWD) (3a)	Riverside County	23,518	39,197	58,796	70,555	78,395	82,314	90,154	117,592	137,191	156,789	195,987
3	Imperial Irrigation District (IID) (3a)	Imperial County	35,634	59,390	89,085	106,902	118,780	124,719	136,597	178,170	207,865	237,560	296,950
2	Yuma Project, Reservation Division (Bard Unit Only - Indian Unit Under PPRs)	Imperial County	520	866	1,300	1,559	1,733	1,819	1,993	2,599	3,032	3,466	4,332
1	Palo Verde Irrigation District - Valley Lands	Riverside, Imperial	26,254	43,756	65,634	78,761	87,512	91,887	100,639	131,268	153,146	175,024	218,779
PPR	PPR No. 32, Sonny Gowan (Grannis)	Imperial County	8	14	21	25	27	29	31	41	48	55	68
PPR	PPR No. 41, Chagnon	San Bernardino	5	9	14	16	18	19	21	27	32	36	46
PPR	PPR No. 36, Colorado River Sportsmen's League	San Bernardino	4	7	11	13	15	15	17	22	26	29	36
PPR	PPR No. 34, Milpitas	Imperial County	5	8	12	15	16	17	19	25	29	33	41
PPR	PPR No. 28, Reservation Division/Yuma Project (non-Indian portion)	Imperial County	1,391	2,318	3,477	4,173	4,637	4,868	5,332	6,955	8,114	9,273	11,592
PPR	PPR No. 27, Imperial Irrigation District & CVWD lands	Imperial County	185,297	308,828	463,242	555,890	617,655	648,538	710,304	926,483	1,080,897	1,235,311	1,544,138
PPR	PPR No. 26, Palo Verde Irrigation District	Riverside, Imperial	6,735	11,225	16,838	20,206	22,451	23,573	25,818	33,676	39,289	44,901	56,127
PPR	PPR No. 42, Lawrence	Imperial County	5	9	14	16	18	19	21	27	32	36	46
PPR	PPR No. 37, Milpitas	Imperial County	3	5	8	9	10	11	12	16	18	21	26
PPR	PPR No. 33, Morgan	Imperial County	7	11	17	21	23	24	26	34	40	46	57
PPR	PPR No. 35, Simons	San Bernardino	3	5	7	8	9	10	10	14	16	18	23
-	-	**Subtotal**	**279,746**	**466,243**	**699,365**	**839,238**	**932,487**	**979,111**	**1,072,360**	**1,398,730**	**1,631,852**	**1,864,974**	**2,331,217**
Nevada			-	-	-	-	-	-	-	-	-	-	-
None	None		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Subtotal**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-	-	**Total**	**338,229**	**563,716**	**845,573**	**1,014,688**	**1,127,431**	**1,183,803**	**1,296,546**	**1,691,147**	**1,973,005**	**2,254,862**	**2,818,578**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	0	0	0	0	0	0	0	0	0	0	0
-	La Paz County	-	834	1,390	2,085	2,503	2,781	2,920	3,198	4,171	4,866	5,561	6,951

Summary of Consumptive Use Impacts to Irrigation			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	Mohave County	-	1,578	2,630	3,945	4,734	5,260	5,523	6,049	7,889	9,204	10,519	13,149
-	Yuma County	-	56,071	93,452	140,178	168,214	186,904	196,249	214,940	280,356	327,082	373,808	467,260
-	**Subtotal Arizona Irrigation**	-	**58,483**	**97,472**	**146,208**	**175,450**	**194,944**	**204,692**	**224,186**	**292,416**	**341,153**	**389,889**	**487,361**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Riverside County	-	40,369	67,282	100,923	121,107	134,564	141,292	154,748	201,846	235,487	269,127	336,409
-	Imperial County	-	239,364	398,941	598,411	718,093	797,881	837,775	917,563	1,196,822	1,396,292	1,595,762	1,994,703
-	San Bernardino	-	13	21	31	38	42	44	48	63	73	84	105
-	**Subtotal California Irrigation**	-	**279,746**	**466,243**	**699,365**	**839,238**	**932,487**	**979,111**	**1,072,360**	**1,398,730**	**1,631,852**	**1,864,974**	**2,331,217**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	None	-	0	0	0	0	0	0	0	0	0	0	0

Disclaimer: These modeling results for the pro rata (w/o Tribal PPR Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]Combined irrigation and domestic entitlement where domestic use is contractually subordinated to irrigation.
[2]Combined irrigation and domestic entitlement where priority of domestic and irrigation uses may be subject to an annual determination that varies based on the water supply conditions.
[3]This user also holds a PPR entitlement.

Table C-58
Pro Rata Without PPR Tribal Shortage Alternative Distribution Model Domestic Summary

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
Arizona			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
CAP NIA-B	Buckeye	Maricopa County	208	347	521	625	695	730	799	1,042	1,216	1,390	1,737
CAP NIA-B	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	1,361	2,268	3,402	4,082	4,536	4,763	5,216	6,804	7,938	9,072	11,340
CAP NIA-B	Carefree Water Company	Maricopa County	8	14	21	25	28	29	32	42	49	56	70
CAP NIA-B	Cave Creek	Maricopa County	29	48	72	87	96	101	111	144	168	193	241
CAP NIA-B	El Mirage	Maricopa County	99	164	247	296	329	345	378	493	575	658	822
CAP NIA-B	EPCOR, San Tan (ST)	Pinal County	241	401	602	722	802	843	923	1,204	1,404	1,605	2,006
CAP NIA-B	Freeport	Pima County	425	708	1,062	1,275	1,416	1,487	1,629	2,124	2,479	2,833	3,541
CAP NIA-B	Gilbert	Maricopa County	137	228	343	411	457	480	526	685	800	914	1,142
CAP NIA-B	Marana	Pima County	39	64	96	116	128	135	148	193	225	257	321
CAP NIA-B	Queen Creek	Maricopa County	311	519	779	934	1,038	1,090	1,194	1,557	1,817	2,076	2,595
CAP NIA-B	Resolution Copper	Maricopa County	167	279	419	502	558	586	642	837	977	1,116	1,396
CAP NIA-B	Rosemont Copper	Pima County	84	140	210	252	280	294	322	421	491	561	701
CAP NIA-B	SRP	Maricopa County	162	269	404	485	539	566	620	808	943	1,078	1,347
CAP NIA-B	Water Utilities Community Facilities District, Apache Junction	Pinal County	61	102	153	183	204	214	234	306	357	408	509
CAP NIA-A	Phoenix	Maricopa County	2,790	4,650	6,974	8,369	9,299	9,764	10,694	13,949	16,273	18,598	23,248
CAP NIA-A	Chandler	Maricopa County	294	489	734	881	979	1,028	1,126	1,468	1,713	1,958	2,447
CAP NIA-A	Gilbert	Maricopa County	115	192	288	345	383	403	441	575	671	767	958
CAP NIA-A	Glendale	Maricopa County	51	85	128	153	170	179	196	255	298	340	425
CAP NIA-A	Mesa	Maricopa County	415	692	1,038	1,246	1,385	1,454	1,592	2,077	2,423	2,769	3,462

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP NIA-A	Scottsdale	Maricopa County	247	412	618	742	825	866	948	1,237	1,443	1,649	2,062
CAP NIA-A	Tempe	Maricopa County	2	3	4	5	6	6	7	9	10	11	14
CAP Indian	Scottsdale (Yavapai Prescott Indian Tribe Allocation)	Maricopa County	37	62	94	112	125	131	143	187	218	249	312
CAP M&I	ASARCO	Pima County	1,571	2,619	3,929	4,714	5,238	5,500	6,024	7,857	9,167	10,476	13,095
CAP M&I	Avondale	Maricopa County	405	675	1,013	1,216	1,351	1,419	1,554	2,026	2,364	2,702	3,377
CAP M&I	Arizona State Land Department (AZSLD)	Maricopa County	2,108	3,514	5,271	6,325	7,028	7,380	8,082	10,542	12,299	14,056	17,570
CAP M&I	Arizona Water Company, Casa Grande	Pinal County	665	1,108	1,662	1,994	2,216	2,327	2,548	3,324	3,878	4,432	5,540
CAP M&I	Arizona Water Company, Coolidge	Pinal County	150	249	374	449	499	524	574	748	873	998	1,247
CAP M&I	Arizona Water Company, Superstition	Pinal County	470	784	1,176	1,411	1,568	1,646	1,803	2,352	2,744	3,135	3,919
CAP M&I	Arizona Water Company, White Tank	Maricopa County	72	121	181	217	241	254	278	362	423	483	604
CAP M&I	Buckeye	Maricopa County	5	8	13	15	17	18	20	25	30	34	42
CAP M&I	Central Arizona Groundwater Replenishment District (CAGRD)	Maricopa County	481	801	1,202	1,443	1,603	1,683	1,843	2,404	2,805	3,206	4,007
CAP M&I	Carefree Water Company	Maricopa County	126	209	314	377	419	439	481	628	732	837	1,046
CAP M&I	Cave Creek	Maricopa County	167	278	417	500	556	584	639	834	973	1,111	1,389
CAP M&I	Chandler	Maricopa County	648	1,079	1,619	1,943	2,159	2,267	2,482	3,238	3,778	4,317	5,397
CAP M&I	Chaparral City Water Company	Maricopa County	667	1,111	1,667	2,000	2,222	2,333	2,556	3,333	3,889	4,444	5,556
CAP M&I	Circle City	Maricopa County	294	490	736	883	981	1,030	1,128	1,471	1,716	1,962	2,452
CAP M&I	El Mirage	Maricopa County	38	63	95	114	127	133	146	190	222	253	317
CAP M&I	Eloy	Pinal County	162	271	406	487	542	569	623	812	948	1,083	1,354
CAP M&I	EPCOR, Agua Fria	Maricopa County	830	1,384	2,075	2,490	2,767	2,905	3,182	4,151	4,842	5,534	6,918
CAP M&I	EPCOR, Paradise Valley	Maricopa County	242	403	604	725	806	846	927	1,209	1,410	1,612	2,015
CAP M&I	EPCOR, Sun City	Maricopa County	313	522	784	940	1,045	1,097	1,202	1,567	1,829	2,090	2,612
CAP M&I	EPCOR, Sun City West	Maricopa County	177	296	444	532	592	621	680	887	1,035	1,183	1,479

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Florence	Pinal County	153	255	383	460	511	536	587	766	894	1,022	1,277
CAP M&I	Freeport-Miami	Gila County	217	362	544	652	725	761	834	1,087	1,269	1,450	1,812
CAP M&I	Flowing Wells Irrigation District (FWID)	Pima County	214	356	534	641	712	747	819	1,068	1,246	1,424	1,780
CAP M&I	Gilbert	Maricopa County	541	902	1,354	1,624	1,805	1,895	2,075	2,707	3,158	3,609	4,512
CAP M&I	Glendale	Maricopa County	1,290	2,150	3,224	3,869	4,299	4,514	4,944	6,449	7,524	8,599	10,748
CAP M&I	Goodyear	Maricopa County	804	1,340	2,010	2,412	2,679	2,813	3,081	4,019	4,689	5,359	6,699
CAP M&I	Greater Tonopah, Water Utility	Maricopa County	5	8	12	14	16	17	18	24	28	32	40
CAP M&I	Green Valley Community Water Company	Pima County	214	356	535	642	713	749	820	1,069	1,248	1,426	1,782
CAP M&I	Green Valley Domestic Water Improvement District	Pima County	142	237	355	427	474	498	545	711	829	948	1,185
CAP M&I	Marana	Pima County	175	291	437	524	583	612	670	874	1,020	1,165	1,457
CAP M&I	Maricopa County Parks & Recreation	Maricopa County	50	83	124	149	166	174	191	249	290	332	415
CAP M&I	Mesa	Maricopa County	3,255	5,426	8,138	9,766	10,851	11,394	12,479	16,277	18,990	21,703	27,128
CAP M&I	Metropolitan Domestic Water Improvement District	Pima County	1,007	1,679	2,518	3,022	3,357	3,525	3,861	5,036	5,876	6,715	8,394
CAP M&I	Oro Valley	Pima County	771	1,285	1,928	2,313	2,570	2,699	2,956	3,856	4,498	5,141	6,426
CAP M&I	Peoria	Maricopa County	2,030	3,383	5,074	6,089	6,765	7,103	7,780	10,148	11,839	13,530	16,913
CAP M&I	Phoenix	Maricopa County	9,437	15,728	23,591	28,310	31,455	33,028	36,173	47,183	55,046	62,910	78,638
CAP M&I	Pine	Gila County	12	20	30	36	40	42	46	60	70	80	100
CAP M&I	Queen Creek	Maricopa County	37	62	93	111	123	130	142	185	216	247	309
CAP M&I	Rio Verde Utilities	Maricopa County	61	101	152	182	203	213	233	304	354	405	506
CAP M&I	San Tan Irrigation District	Maricopa County	18	29	44	53	59	62	68	88	103	118	147
CAP M&I	Scottsdale	Maricopa County	3,952	6,586	9,880	11,856	13,173	13,831	15,149	19,759	23,052	26,346	32,932
CAP M&I	Spanish Trail Water Company	Pima County	227	379	568	682	758	795	871	1,136	1,326	1,515	1,894
CAP M&I	Surprise	Maricopa County	767	1,278	1,917	2,301	2,556	2,684	2,940	3,835	4,474	5,113	6,391

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
CAP M&I	Tempe	Maricopa County	323	538	807	969	1,076	1,130	1,238	1,614	1,884	2,153	2,691
CAP M&I	Tonto Hills Domestic Water Improvement District	Maricopa County	5	9	13	16	18	19	20	27	31	35	44
CAP M&I	Tucson	Pima County	10,790	17,983	26,975	32,370	35,967	37,765	41,362	53,950	62,942	71,933	89,917
CAP M&I	Vail Water Company	Pima County	139	232	347	417	463	486	533	695	811	926	1,158
CAP M&I	Water Utilities Community Facilities District, Apache Junction	Pinal County	218	364	546	655	728	765	837	1,092	1,274	1,456	1,820
4(i)	Arizona State Land Department	Yuma County	70	117	175	210	233	245	268	350	408	466	583
4(i)	Arizona State Parks Board - Windsor Beach	Mohave County	4	7	10	13	14	15	16	21	24	28	35
4(i)	B&F Investment, LLC	La Paz County	3	5	7	9	10	10	11	15	17	20	25
4(i)	Bullhead City	Mohave County	715	1,192	1,789	2,146	2,385	2,504	2,742	3,577	4,173	4,770	5,962
4(i)	Bullhead City (Mohave County Water Authority (MCWA) Subcontract)	Mohave County	101	168	252	302	335	352	386	503	587	671	838
4(i)	Bullhead City (MCWA Subcontract)	Mohave County	329	549	823	988	1,098	1,152	1,262	1,646	1,921	2,195	2,744
4(i)	Bureau of Land Management	La Paz County	286	476	714	857	953	1,000	1,095	1,429	1,667	1,905	2,381
4(i)	Crystal Beach Water Conservation District	Mohave County	6	10	15	18	20	21	23	31	36	41	51
4(i)	Ehrenburg Improvement District	La Paz County	33	55	83	99	110	116	127	165	193	220	275
4(i)	EPCOR Water Arizona Inc.[1]	Mohave County	88	147	220	264	294	309	338	441	514	588	735
4(i)	Fisher's Landing Water and Sewer Works, L.L.C.	Yuma County	3	4	6	8	8	9	10	13	15	17	21
4(i)	Frontier Communications West Coast Inc.	La Paz County	0	0	0	0	0	0	0	0	0	0	1
4(i)	Gold Dome Mining Corporation	Yuma County	0	1	1	1	2	2	2	2	3	3	4
4(i)	Golden Shores Water Conservation District	Mohave County	95	159	239	286	318	334	366	477	557	637	796
4(i)	GSC Farm, LLC	La Paz County	4	6	9	11	12	13	14	18	21	24	30
4(i)	Hillcrest Water Company	La Paz County	4	6	10	12	13	14	15	19	23	26	32
4(i)	Lake Havasu City	Mohave County	848	1,413	2,120	2,544	2,827	2,968	3,251	4,240	4,947	5,654	7,067
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	95	158	236	284	315	331	362	473	551	630	788

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
4(i)	Lake Havasu City (MCWA Subcontract)	Mohave County	320	534	801	961	1,068	1,121	1,228	1,602	1,869	2,136	2,670
4(i)	La Paz County	La Paz County	25	42	62	75	83	87	96	125	146	166	208
4(i)	Martinez Lake Cabin Sites	Yuma County	1	2	3	3	3	4	4	5	6	7	9
4(i)	McAlister Family Trust	Mohave County	2	3	5	6	7	7	8	10	11	13	16
4(i)	Mohave Valley Irrigation and Drainage District (MCWA Subcontract)	Mohave County	48	80	120	144	160	168	184	241	281	321	401
4(i)	Mohave Water Conservation District	Mohave County	86	143	215	258	286	301	329	430	501	573	716
4(i)	Mohave Water Conservation District (MCWA Subcontract)	Mohave County	143	239	358	430	477	501	549	716	836	955	1,194
4(i)	Parker, Town of[1]	La Paz County	31	51	77	92	103	108	118	154	180	206	257
4(i)	Quartzsite, Town of	La Paz County	76	127	191	229	254	267	292	381	445	508	635
4(i)	Queen Creek, Town of	Maricopa County	145	241	362	435	483	507	555	724	845	966	1,207
4(i)	Roy, Estates of Anna R. and Edward P.	Yuma County	0	0	0	0	0	0	0	0	0	0	1
4(i)	Shepard Water Company, Incorporated	Yuma County	2	4	6	7	8	8	9	12	14	15	19
4(i)	Somerton, City of	Yuma County	53	89	134	160	178	187	205	267	312	356	445
4(i)	Springs Del Sol Domestic Water Improvement District	La Paz County	5	9	13	16	17	18	20	26	30	35	43
4(i)	TV Marble Canyon AZ, LLC	Coconino County	3	5	8	10	11	11	12	16	19	22	27
3	City of Yuma[1]	Yuma County	3,458	5,763	8,645	10,374	11,527	12,103	13,256	17,290	20,172	23,054	28,817
3	Union Pacific Railroad (formerly Southern Pacific Co.)	Yuma County	2	3	5	5	6	6	7	9	11	12	15
3	Kaman, Inc.	Yuma County	0	0	0	0	0	0	1	1	1	1	1
3	Department of the Navy, MCAS	Yuma County	214	356	535	641	713	748	820	1,069	1,247	1,425	1,782
3	City of Yuma (cemetery)	Yuma County	4	7	11	13	14	15	16	21	25	29	36
3	Yuma Mesa Fruit Growers' Association	Yuma County	1	2	3	3	4	4	4	5	6	7	9
3	Desert Lawn Memorial Park Association	Yuma County	10	16	25	30	33	34	38	49	57	66	82

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
3	Chandler (Salt River Pima-Maricopa Exchange)	Maricopa County	305	508	762	915	1,016	1,067	1,169	1,524	1,778	2,033	2,541
3	Gilbert (Salt River Pima-Maricopa Exchange)	Maricopa County	482	803	1,205	1,446	1,606	1,687	1,847	2,410	2,811	3,213	4,016
3	Glendale (Salt River Pima-Maricopa Exchange)	Maricopa County	214	356	535	641	713	748	820	1,069	1,247	1,425	1,782
3	Mesa (Salt River Pima-Maricopa Exchange)	Maricopa County	197	328	492	590	656	688	754	983	1,147	1,311	1,639
3	Phoenix (Salt River Pima-Maricopa Exchange)	Maricopa County	356	594	891	1,069	1,188	1,247	1,366	1,782	2,079	2,376	2,969
3	Scottsdale (Salt River Pima-Maricopa Exchange)	Maricopa County	7	12	18	21	24	25	27	36	42	48	59
3	Tempe (Salt River Pima-Maricopa Exchange)	Maricopa County	7	12	18	21	24	25	27	36	42	48	59
3	Department of the Army - Yuma Proving Ground	Yuma County	80	134	201	241	268	282	308	402	469	536	671
3	Yuma Union High School District	Yuma County	11	18	26	32	35	37	40	53	62	70	88
3	Desert Lawn Memorial Park Association, Inc.	Yuma County	18	30	44	53	59	62	68	89	103	118	148
2	Cibola National Wildlife Refuge	La Paz County	1,197	1,995	2,992	3,590	3,989	4,189	4,588	5,984	6,981	7,979	9,973
2	Lake Mead National Recreation Area	Mohave County	24	41	61	73	81	86	94	122	143	163	204
2	Bureau of Reclamation - Davis Dam	Mohave County	0	1	1	1	2	2	2	2	3	3	4
2	Imperial National Wildlife Refuge	La Paz County	1,639	2,732	4,098	4,917	5,464	5,737	6,283	8,196	9,562	10,928	13,660
2	Havasu Lake National Wildlife Refuge	Mohave County	2,665	4,442	6,663	7,996	8,884	9,329	10,217	13,327	15,548	17,769	22,211
1	PPR No. 9, EPCOR CSA #2 (Formerly Brooke Water Company) (Graham)	La Paz County	17	28	42	51	56	59	65	85	99	113	141
1	PPR No. 20, Parker, City of	La Paz County	29	48	71	86	95	100	109	143	166	190	238
1	PPR No. 21, Yuma, City of	Yuma County	105	176	263	316	351	369	404	527	614	702	878
-	-	**Subtotal**	**68,398**	**113,997**	**170,996**	**205,195**	**227,994**	**239,394**	**262,193**	**341,991**	**398,990**	**455,989**	**569,986**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)									
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
California			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
4	Metropolitan Water District of Southern California (MWD) (4)	Los Angeles, Orange, San Diego, Riverside, San Bernardino	27,652	46,087	69,130	82,956	92,174	96,782	106,000	138,260	161,304	184,347	230,434
PPR	PPR No. 59, Diehl	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 66, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 77, Estrada	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 79, Corrington	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 80, Tolliver	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 65, Randolph	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 67, Keefe	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 48, Faubion	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 58, Earle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 78, Whittle	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 51, Beauchamp	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 63, McGee	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 64, Stallard	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 72, Hadlock	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 30, Stephenson	San Bernardino	11	18	27	33	36	38	42	55	64	73	91
PPR	PPR No. 46, Draper, G.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 49, Dudley	San Bernardino	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 38, Andrade	San Bernardino	3	5	8	9	10	11	12	15	18	20	25

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 45, Conger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 70, Vaulin	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 71, Salisbury	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 47, McDonough	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 62, Cate	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 56, Schneider	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 50, Douglas	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 52, Clark	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 61, Graham	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 53, Lawrence	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 54, Graham, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 60, Reid	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 75, Fitz	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 55, Geiger	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 76, Williams	Riverside County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 40, Cooper	San Bernardino	3	5	7	8	9	10	10	14	16	18	23
PPR	PPR No. 39, Reynolds	San Bernardino	2	3	4	5	5	6	6	8	10	11	14
PPR	PPR No. 68, Ferguson, C.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 69, Ferguson, W.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 73, Streeter	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 74, Draper, J.	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 44, City of Needles (formerly Atchison, Topeka, and Santa Fe Railway Co.)	San Bernardino	19	32	49	58	65	68	75	97	113	130	162

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-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
PPR	PPR No. 57, Martinez	Imperial County	0	0	0	0	0	0	0	0	0	0	0
PPR	PPR No. 31, Mendivil (Picacho Development Corp and CA Dept of Parks and Rec)	Imperial County	5	9	14	16	18	19	21	27	32	36	46
PPR	PPR No. 43, City of Needles	San Bernardino	68	113	169	203	226	237	260	339	395	451	564
PPR	PPR No. 29, Yuma Associates LTD and Winterhaven Water District (formerly Wavers)	Imperial County	36	59	89	107	119	125	136	178	208	237	296
-	-	**Subtotal**	**27,800**	**46,334**	**69,500**	**83,401**	**92,667**	**97,301**	**106,567**	**139,001**	**162,168**	**185,334**	**231,668**
Nevada			-	-	-	-	-	-	-	-	-	-	-
Priority	**Entitlement Holder**	**County**	-	-	-	-	-	-	-	-	-	-	-
8 - Balance & Surplus	Southern Nevada Water Authority (SNWA)	Clark	6,608	11,013	16,519	19,823	22,026	23,127	25,330	33,039	38,545	44,051	55,064
8	Big Bend Water District	Clark	349	582	873	1,048	1,164	1,222	1,339	1,746	2,037	2,328	2,910
8	Robert B. Griffith Project	Clark	11,266	18,777	28,165	33,798	37,553	39,431	43,186	56,330	65,719	75,107	93,884
7	Southern Nevada Water Authority (Formerly Boy Scouts of America)	Clark	0	1	1	1	1	1	1	2	2	2	3
7	Bureau of Reclamation (includes Sportsman Park)	Clark	10	17	26	31	35	37	40	52	61	70	87
7	Nevada Dept. of Wildlife (formerly NV Dept of Game & Fish)	Clark	2	3	4	5	6	6	7	9	10	12	15
7	U.S. Air Force (4.0 kaf) (Delivery from SNWA)	Clark	148	247	371	445	494	519	568	741	865	988	1,235
6	Las Vegas Valley Water District	Clark	571	952	1,427	1,713	1,903	1,998	2,189	2,855	3,331	3,806	4,758
5	Pacific Coast Building Products, Inc. (PABCO)	Clark	34	57	86	103	115	120	132	172	201	229	287
4	Henderson Water Company (formerly BMI/Basic Water Company)	Clark	304	507	760	913	1,014	1,065	1,166	1,521	1,774	2,028	2,535
4	City of Henderson	Clark	588	981	1,471	1,765	1,961	2,059	2,256	2,942	3,432	3,923	4,904
4	Southern Nevada Water Authority (From Basic Water Company)	Clark	554	923	1,385	1,662	1,847	1,939	2,124	2,770	3,232	3,694	4,617
3	Boulder City	Clark	218	363	544	653	726	762	835	1,089	1,270	1,452	1,815
2	Lake Mead National Recreation Area, Executive Order No. 5339	Clark	107	178	267	321	356	374	410	535	624	713	891
1	PPR No. 82, Lake Mead National Recreation Area (Overton Area, EO 5105)	Clark	21	36	53	64	71	75	82	107	125	143	178
-	-	**Subtotal**	**20,782**	**34,636**	**51,955**	**62,346**	**69,273**	**72,737**	**79,664**	**103,909**	**121,228**	**138,546**	**173,182**

Summary of Consumptive Use Impacts to Domestic Uses			Range of Analyzed Volumes of Total Shortage to Lower Basin for the Pro Rata (w/o Tribal PPR Shortage) Alternative Distribution (af)										
-			600,000	1,000,000	1,500,000	1,800,000	2,000,000	2,100,000	2,300,000	3,000,000	3,500,000	4,000,000	5,000,000
-	-	**Total**	**116,980**	**194,967**	**292,451**	**350,941**	**389,934**	**409,431**	**448,425**	**584,902**	**682,385**	**779,869**	**974,836**
Summary by County													
-	**Arizona**	-	-	-	-	-	-	-	-	-	-	-	-
-	Coconino County	-	3	5	8	10	11	11	12	16	19	22	27
-	Gila County	-	230	383	574	689	765	803	880	1,148	1,339	1,530	1,913
-	La Paz County	-	3,348	5,580	8,370	10,044	11,160	11,718	12,834	16,740	19,529	22,319	27,899
-	Maricopa County	-	37,294	62,157	93,235	111,883	124,314	130,530	142,961	186,471	217,549	248,628	310,785
-	Mohave County	-	5,572	9,286	13,929	16,715	18,572	19,501	21,358	27,859	32,502	37,145	46,431
-	Pima County	-	15,798	26,330	39,495	47,394	52,660	55,293	60,559	78,990	92,155	105,320	131,650
-	Pinal County	-	2,121	3,535	5,302	6,362	7,069	7,423	8,130	10,604	12,371	14,139	17,673
-	Yuma County	-	4,033	6,722	10,082	12,099	13,443	14,115	15,460	20,165	23,525	26,886	33,608
-	**Subtotal Arizona Domestic**	-	**68,398**	**113,997**	**170,996**	**205,195**	**227,994**	**239,394**	**262,193**	**341,991**	**398,990**	**455,989**	**569,986**
-	**California**	-	-	-	-	-	-	-	-	-	-	-	-
-	Los Angeles, Orange, San Diego, Riverside, San Bernardino	-	27,652	46,087	69,130	82,956	92,174	96,782	106,000	138,260	161,304	184,347	230,434
-	Imperial County	-	42	71	106	127	141	148	162	212	247	282	353
-	Riverside County	-	0	0	1	1	1	1	1	1	1	1	2
-	San Bernardino	-	106	176	264	317	352	369	405	528	616	704	879
-	**Subtotal California Domestic**	-	**27,800**	**46,334**	**69,500**	**83,401**	**92,667**	**97,301**	**106,567**	**139,001**	**162,168**	**185,334**	**231,668**
-	**Nevada**	-	-	-	-	-	-	-	-	-	-	-	-
-	Clark	-	20,782	34,636	51,955	62,346	69,273	72,737	79,664	103,909	121,228	138,546	173,182
-	**Subtotal Nevada Domestic**	-	**20,782**	**34,636**	**51,955**	**62,346**	**69,273**	**72,737**	**79,664**	**103,909**	**121,228**	**138,546**	**173,182**

Disclaimer: These modeling results for the pro rata (w/o Tribal PPR Shortage) alternative distribution should only be used to compare the relative magnitude of effects reasonably expected to occur under the alternatives evaluated in this EIS. Modeling assumptions should not be taken as agency position with respect to contract or statutory interpretation, and are not intended to limit Secretarial discretion with respect to current or future policy. This model is not a substitute for the annual process of reviewing water orders and determining which can be filled, and cannot replicate the precision required of that process.

Note: Orange highlights indicate the level at which available water for a priority is reduced. Lighter orange indicates smaller reductions, while the darkest orange indicates a priority is reduced to zero (does not occur in this table).
Note: This analysis does not reflect an operational estimate of when water may cease to be physically available to certain users.
[1]This user also holds a PPR entitlement.
[2]Likely to include domestic, irrigation, and tribal elements (including an unquantified entitlement for the Cocopah Reservation's 1985 lands)

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Attachment C-1

Exhibit 5.3.4.1 to the Tohono O'odham Settlement Agreement, *Secretary's Approach for Determining the Amount of Water Available to the Nation During a Time of Shortage Under 1980 Contract*

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EXHIBIT 5.3.4.1

SECRETARY'S SHORTAGE SHARING APPROACH

UNDER THE 1980 CONTRACT

Secretary's Approach for Determining
The Amount of Water Available to the Nation
During a Time of Shortage Under 1980 Contract

If the Available CAP Supply is insufficient to fill all orders for CAP water, the Secretary shall take the following steps, in succession, as necessary to match the available supply with orders for the delivery of CAP water in each of the categories described below:

1. First, miscellaneous uses of CAP water are reduced, pro rata. If, after eliminating all miscellaneous uses of CAP water, there is still insufficient available CAP water to meet outstanding orders for the delivery of CAP water, the Secretary shall take the following measure.

2. Uses of CAP NIA Priority Water are reduced, pro rata. If, after eliminating all uses of CAP NIA Priority Water, there is still insufficient available CAP water to meet outstanding orders for delivery of CAP water, then the Secretary shall take the following measure.

3. Uses of CAP M&I Priority Water in excess of 510,000 acre-feet are reduced, pro rata. If, after eliminating all uses of CAP M&I Priority Water in excess of 510,000 acre-feet, there is still insufficient available CAP water to meet outstanding orders for delivery of CAP water, then the Secretary shall take the following measure.

4. If the preceding reductions do not bring CAP water orders in line with the Available CAP Supply, uses of CAP Indian Priority Water in excess of 291,574 acre-feet are reduced, in accordance with the Secretarial Decision published in the Federal Register on March 24, 1983.

5. If the preceding reductions do not bring CAP water orders in line with the Available CAP Supply, the available CAP water supply will be allocated between users of CAP Indian Priority Water and users of CAP M&I Priority Water on a 36.37518 and 63.62482 percentage basis, respectively.

6. If step 5 is implemented, the amount of water available for the Nation shall be determined by multiplying the amount of CAP Indian Priority Water by the ratio of the amount of water delivered pursuant to the Nation's CAP Water Delivery Contract in the latest non-shortage Year relative to the total quantity of water delivered to all CAP Contracts for Indian Priority Water in that same Year.

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Appendix D

Sensitivity Analysis – Effects of Natural Flow Percentage Used for the Supply Driven Alternative

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APPENDIX D. SENSITIVITY ANALYSIS – EFFECTS OF NATURAL FLOW PERCENTAGE USED FOR THE SUPPLY DRIVEN ALTERNATIVE..... D-1

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Figure

D-1 Response of Key Variables to Different Natural Flow Release Percentages for Lower Basin Priority (dark color) and Lower Basin Pro Rata (light color) Shortage Distribution Methods D-4

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
EIS	environmental impact statement
EOWY	end-of-water year
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
Mexico	United Mexican States
U.S.	United States

Appendix D. Sensitivity Analysis – Effects of Natural Flow Percentage Used for the Supply Driven Alternative

D.1 Introduction

The Supply Driven Alternative (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) described in **Appendix S** of this Final Environmental Impact Statement (EIS) assumes 65 percent of the preceding 3-year Lees Ferry natural flow is released from Lake Powell, with annual releases constrained between 4.7 and 12.0 million acre-feet (maf). This sensitivity analysis explores the impacts of adjusting the assumed natural flow release percentage, specifically comparing 60 percent, 65 percent, and 70 percent, on key hydrologic and water delivery resources.

D.2 Modeling Results

An analysis was performed to test the sensitivity of the hydrologic and water delivery resources to three different natural flow release percentages (60 percent, 65 percent, and 70 percent). The Colorado River Simulation System (CRSS) model was used to simulate operations under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) with these three different natural flow release percentages, while holding all other modeling assumptions under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) constant. See **Appendix A**, CRSS Model Documentation, for detailed modeling assumptions.

Figure D-1 compares the response of key variables to different hydrologic conditions for the different scenarios that vary the natural flow release percentages and Lower Basin shortage distribution methods (both LB Priority and LB Pro Rata approaches). Results are presented using conditional boxplots, which separate results based on five flow categories (see **Chapter 3.2.6** for additional details on conditional boxplots). Each boxplot in the figure illustrates the distribution of modeled results, where the bold center line represents the median value, the top and bottom of each box shows the interquartile range which captures the 25th to 75th percentile, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines. The following sections compare the responses of key variables to different natural flow release percentages by hydrologic conditions.

D.2.1 Water Year Gap Water Volume

In years when Lake Powell cannot meet its required water year release because of low elevation infrastructure constraints (i.e., Lake Powell is less than 3,490 feet), additional water is introduced

into the system to (partially) make up the shortfall. For modeling purposes, this supplemental volume is termed "gap water." Gap water is injected into Lake Powell and released when conditions allow, subject to the same low-elevation release constraints. Any portion not released in a given water year is tracked as carryover and released in subsequent years. The annual amount of gap water is limited to no more than 23 percent[1] of the Upper Basin's modeled depletion for that year, minus any Upper Basin conservation that occurs. Additional detail is provided in **Appendix A**.

Water year gap water volume is shown in the first column of **Figure D-1**. In the Average Flow Category (12.0-14.0 maf), the median and upper quartile gap water volume is zero at the 60 and 65 percent natural flow release percentages. For the 70 percent natural flow release scenario, the median and upper quartile are slightly over 0.1 maf and 0.9 maf, respectively. As the hydrologic conditions become drier, the gap water volume increases across all scenarios. In the Critically Dry Flow Category (4.5-10.0 maf), the median for the 70 percent natural flow release scenario is 0.8 maf but is zero for 60 percent and 65 percent. With higher natural flow release percentages, the gap water volumes increase and are required more frequently, especially in drier flow conditions, since more Lake Powell releases are infrastructure constrained. Results do not vary with Lower Basin shortage distribution method.

D.2.2 Lake Powell and Lake Mead Water Surface Elevations

Lake Powell and Lake Mead end-of-water year (EOWY) elevation by hydrologic condition are shown in the second and third columns of **Figure D-1**, respectively. Across all flow categories, as the natural flow release percentage increases, the elevation of Lake Powell declines due to higher releases, while Lake Mead elevations increase due to higher inflows.

In the Average Flow Category, median Lake Powell EOWY elevation is 3,633 feet, 3,573 feet, and 3,528 feet in the 60 percent, 65 percent, and 70 percent natural flow release scenarios, respectively, and the bottom quartile of the 70 percent extends below 3,500 feet. In the Critically Dry Flow Category, the median elevation of the 65 percent and 70 percent natural flow release scenarios are nearly at or below 3,500 feet, while the median of the 60 percent scenario is at 3,550 feet. The bottom quartile of the 65 percent and 70 percent scenarios are similar at 3,470 and 3,464 feet, respectively, since releases are limited by infrastructure. The results do not vary by Lower Basin shortage distribution method.

In the Average Flow Category for Lake Mead, the median EOWY elevations are 1,088 feet, 1,146 feet, and 1,173 feet in the 60 percent, 65 percent, and 70 percent scenarios for the LB Priority shortage distribution, and 1,111 feet, 1,158 feet, and 1,181 feet in the 60 percent, 65 percent, and 70 percent scenarios for the LB Pro Rata shortage distribution. The elevation statistics are higher with LB Pro Rata than LB Priority because user-level conservation activity modeling assumptions cause higher volumes of conserved water to be stored in Lake Mead. In the Critically Dry Flow Category, the median elevation of the 60 percent with the LB Priority shortage distribution is below 975 feet, while the 65 and 75 percent scenarios have medians above 1,000 feet. The bottom quartile extends

[1] The 23 percent limit is based on the ratio of the maximum Lower Basin shortage (2.1 maf) to the total Lower Basin apportionment to the United States (U.S.) and the United Mexican States (Mexico) (9.0 maf).

below 1,011 feet in all but the 70 percent scenario, with a median value of 1,025 feet, natural flow release scenario with LB Pro Rata shortage distribution.

D.2.3 Glen Canyon 10-Year Release Volume

Glen Canyon 10-year release volume by hydrologic condition is shown in the fourth column of **Figure D-1**. In the Average Flow Category, the median 10-year releases are 76.7, 81.7 and 86.9 maf in the 60 percent, 65 percent, and 70 percent natural flow release percent scenarios, respectively. The bottom quartile of the 60 percent scenario extends below 75.0 maf and the 65 percent and 70 percent scenario extends below 82.5 maf. In the Critically Dry Flow Category, the median 10-year releases are 69.8, 73.5 and 76.3 maf in the 60 percent, 65 percent, and 70 percent scenarios, with the 60 percent and 65 percent scenario medians below the 75.0 maf volume. All upper quartiles are below the 82.5 maf threshold. The results do not vary by shortage distribution method.

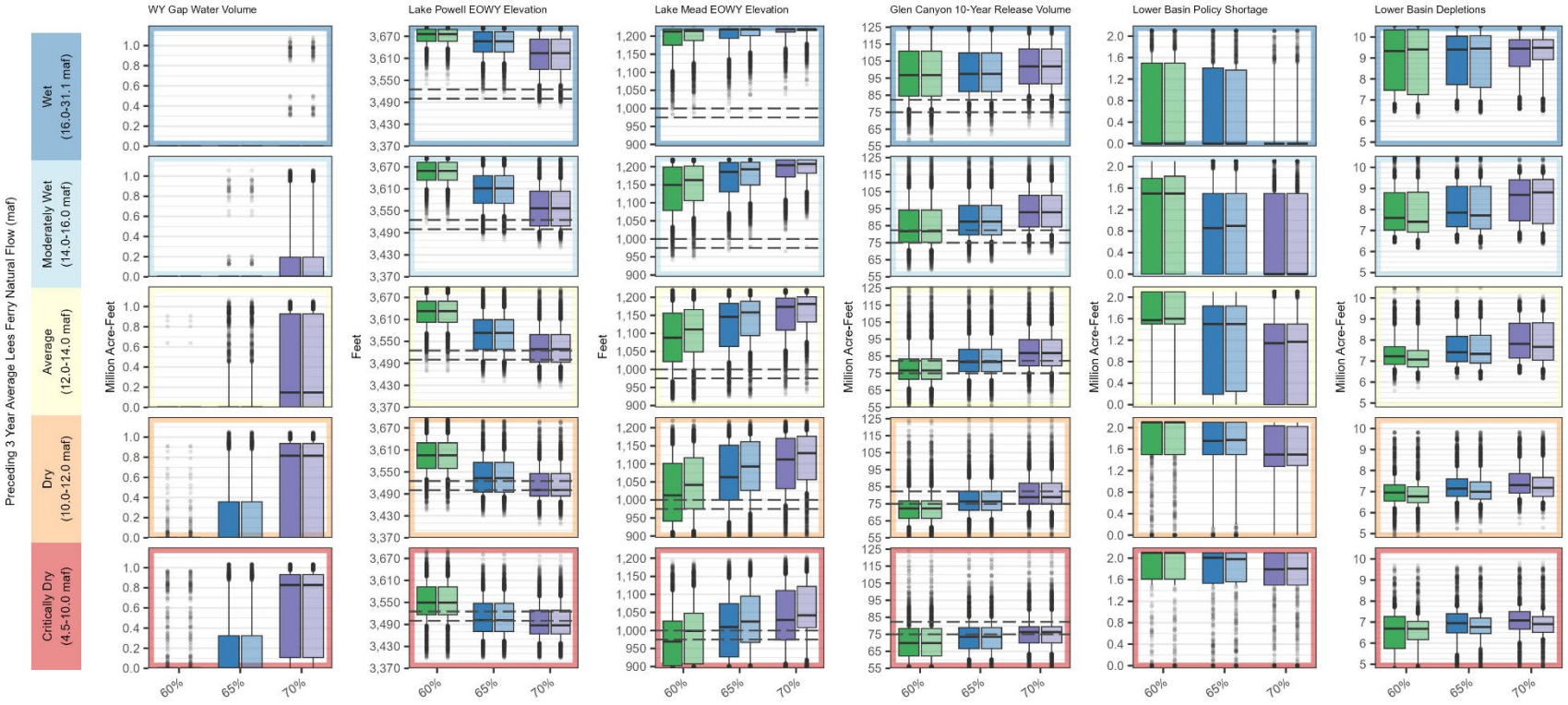
D.2.4 Lower Basin Shortage and Depletion

The Lower Basin shortage and depletion[2] by hydrologic condition are shown in the fifth and sixth columns of **Figure D-1**. The Lower Basin shortage decreases with increasing natural flow release percentage. The shortage distribution approach has only minor impacts on the shortage because the conservation mechanism is operationally neutral and therefore not visible to shortage determination. In the Average Flow Category, the median Lower Basin shortage is 1.6 maf and 1.5 maf in the 60 percent and 65 percent scenarios, respectively, and between 1.1 maf to 1.2 maf for the 70 percent scenarios. The interquartile range (0.6 maf) for the 60 percent scenario is smaller, extending from 1.5 maf to 2.1 maf, compared to the 65 percent and 70 percent scenarios that have interquartile ranges around 1.5 maf. In the Critically Dry Flow Category, the median Lower Basin shortages are all greater than 1.5 maf at 2.1, 2.0, and 1.8 maf in the 60 percent, 65 percent, and 70 percent scenarios, respectively.

As shown in **Figure D-1**, the Lower Basin depletions increase with increasing natural flow release percentage in both shortage distribution methods. The variations in Lower Basin depletions between the LB Pro Rata and LB Priority methods shown in **Figure D-1** is the result of conservation activity modeling in the LB Pro Rata method. Though the Lower Basin shortages are similar between the shortage distribution methods, conservation activity modeling assumptions cause different depletions. In the Average Flow Category, the median depletions are 7.2, 7.4, and 7.8 maf in the 60 percent, 65 percent, and 70 percent scenarios, respectively, for the LB Priority shortage distribution, and 7.1, 7.3, and 7.7 maf in the 60 percent, 65 percent, and 70 percent scenarios, respectively, for the LB Pro Rata shortage distribution. In the Critically Dry Flow Category, the median depletions are 6.7, 6.9 and 7.1 maf in the 60 percent, 65 percent, and 70 percent scenarios, respectively, for the LB Priority shortage distribution, and 6.7, 6.8 and 6.9 maf in the 60 percent, 65 percent, and 70 percent scenarios, respectively, for the LB Pro Rata shortage distribution.

[2] The total Lower Basin policy shortage and Lower Basin depletions include shortages to U.S. Lower Division States and water delivery reductions to Mexico based on the modeling assumptions for the distribution of shortages in the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative. The Bureau of Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

Figure D-1
Response of Key Variables to Different Natural Flow Release Percentages for Lower Basin Priority (dark color) and Lower Basin Pro Rata (light color) Shortage Distribution Methods



Appendix E

DMDU Overview and Approach

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
Mexico	United Mexican States
PRIM	Patient Rule Induction Method
Reclamation	Bureau of Reclamation

Appendix E. DMDU Overview and Approach

E.1 Introduction

Uncertainty is a major challenge for the Post-2026 planning process. In the medium-to- long-term (e.g. 5 to 30 years), future streamflow conditions are the predominant driver of the impacts associated with each alternative (Smith et al. 2022). Future hydrology is expected to be drier (Lukas and Payton 2020, p. 385, 2020; Salehabadi et al. 2022; Wang et al. 2025), but the magnitude and rate of drying is unknown. Not only are future streamflow conditions uncertain, but there is no scientific consensus on how to characterize the uncertainty probabilistically (i.e. the likelihood that a given hydrologic scenario will occur). This is known as deep uncertainty (Lempert et al. 2003; Kwakkel and Haasnoot 2019).

The analytical framework used in this Final Environmental Impact Statement (EIS), called Decision Making under Deep Uncertainty (DMDU), is a non-probabilistic approach that seeks to provide reliable conclusions about robustness – the ability of an alternative to perform acceptably well across a broad range of future conditions (McPhail et al. 2018; Bonham et al. 2024) – and vulnerability – conditions associated with an alternative performing poorly (Bryant and Lempert 2010; Bonham et al. 2025). The Bureau of Reclamation (Reclamation) chose this framework based on the best available science, as explained in Smith et al. 2022.

The purpose of this appendix is to provide an overview of DMDU, document the specific implementation in this Final EIS, and describe the collaborative process that enabled its implementation.

This appendix is structured as follows. **Section E.2**, Background, motivates the need for DMDU and provides an overview of key concepts. **Section E.3**, Methods, describes the specific methods used in this Final EIS. **Section E.4**, Outreach and Collaboration, describes the training and collaborative efforts that were necessary to use DMDU in this Final EIS. **Section E.5** provides a summary of previous sections.

E.2 Background

Uncertainty is often accounted for using probabilistic risk analysis, but risk analysis has several limitations for problems facing deep uncertainty. Risk analysis, in this context, uses a simulation model (such as the Colorado River Simulation System [CRSS]) to evaluate system outcomes over time (such as monthly reservoir elevations) across an ensemble of traces (Wheeler et al. 2022; Reclamation 2024). Then, risk can be evaluated as the percent of traces in which a critical performance threshold is crossed, for example, percent of traces where Lake Powell elevation falls below minimum power pool (3,490 feet).

Each ensemble represents a narrative or a set of assumptions about the future, such as "future hydrology has similar magnitudes to the past 30 years" (Lukas and Payton 2020, p. 346) or "future hydrology will continue to decline at current trends but with increased variability" (Salehabadi et al. 2025). Understanding this assumption is critical because risk percentages can be highly sensitive to the set of traces used. If there is uncertainty about the most appropriate set of assumptions, i.e., deep uncertainty, it is difficult to have confidence in any specific risk percentage, much less determine that it is sufficiently low. If the future proves to be more difficult than the assumed ensemble suggests, risk analysis can lead to a narrow view of what negative impacts are plausible and unintentionally steer decision-makers away from addressing them; if a future is more favorable than was assumed, the analysis can result in decisions that are unnecessarily expensive or austere.

As an alternative to risk-based decision making, DMDU is a well-established branch of decision science that seeks to provide reliable and actionable information about decision alternatives when faced with deep uncertainty (Kasprzyk et al. 2013; Herman et al. 2015; Maier et al. 2016; Marchau et al. 2019; Hadjimichael et al. 2020).

DMDU has three key elements: testing decision alternatives in a broad range of plausible future conditions, robustness analysis, and vulnerability analysis. This section explains these concepts in the context of this Final EIS to provide concrete examples.

1) Each alternative is tested using simulation models in a large ensemble of streamflow traces. This ensemble is statistically designed to include a broad range of conditions, including those outside of the observed record, and the design also minimizes "gaps" in the types of conditions being tested (See **Appendix F**, Approach to Hydrologic Uncertainty). The goal is to maximize the available information about how each alternative performs across a diverse set of traces, rather than predicting the likelihood of an outcome.

2) Alternatives are ranked according to their ability to maintain a specified performance level across a large percentage of traces (robustness). Robustness differs from risk because a) the set of traces being evaluated explores a much broader set of conditions and b) the emphasis is relative comparison of the alternatives (i.e. ranking from most to least robust) rather than a likelihood of success or failure.

3) Vulnerability analysis discovers the conditions in which an alternative is likely to satisfy or fail to meet a given performance level. Here "conditions" refer to the values of statistics describing annual natural flow at Lees Ferry in each streamflow trace. Example streamflow statistics include average annual streamflow during the worst 10-year drought and the driest single year (see **Section E.3**). An example conclusion from vulnerability analysis is that the Basic Coordination Alternative is likely to fall below 3,500 feet if there is a 10-year drought drier than 12.2 maf/year, on average (see **Figure TA 3-8** in **TA 3,** Hydrologic Resources). This is powerful information because it does not depend on any single hydrology ensemble being the "correct" representation of the future (recall, deep uncertainty means there is no consensus on what future hydrology is "correct"). And, when compared to historical extremes, it provides actionable insights. For example, the worst 10-year drought on record averaged 11.8 maf/year (2012-2021). So, unless future conditions are wetter than recent

hydrology, it can reasonably be expected that the Supply Driven Alternative (both Lower Basin Priority and Lower Basin Pro Rata approaches) will result in Lake Powell falling below 3,500 feet.

E.3 Methods

DMDU begins by evaluating each decision alternative in a large set of traces using simulation models. The set of traces used in this study includes 400 hydrologic traces (see **Appendix F**, Approach to Hydrologic Uncertainty). In this Final EIS, each of the 400 hydrologic traces were combined with 3 sets of initial reservoir storage conditions (see **Appendix G**, CRSS Initial Conditions) for a total of 1,200 simulations per alternative per model. Due to recent dry hydrology, however, the high and middle initial conditions are no longer plausible, and this Final EIS considers only the low initial conditions (meaning there are 400 future simulations per alternative per model). Each combination of a hydrologic trace and initial condition is called a future.

Because this Final EIS covers many resources, many models were used, such as CRSS (hydrologic and water deliveries resources), GTMax (electrical power resources), temperature models (water quality and fish resources), smallmouth bass models, and dust emission models (air quality), to name a few (see the technical appendices in **Volume III** for more information). The modeling period covers January 2027 to December 2060. These model runs produce large datasets describing how each alternative performs over time across various streamflow conditions. These datasets are then analyzed in the robustness and vulnerability analyses.

In this Final EIS, robustness is defined as the percent of futures where a performance goal is satisfied (called the satisficing metric in DMDU literature) (McPhail et al. 2018; Bonham et al. 2024). Various other robustness metrics exist, but satisficing was chosen because the performance criteria can be tailored to each resource based on expert input (see **Section E.4**), and because it provides a clear connection to vulnerability analysis. Performance goals are defined using four components: a timeseries, a threshold, a preferred direction, and a frequency. For example, **Figure TA 3-7** in **TA 3,** Hydrologic Resources evaluates the percent of futures in which monthly Lake Powell elevation (the timeseries) stays above (the preferred direction) 3,500 feet (the threshold) in 100 percent of months (the frequency). Robustness is evaluated for each alternative, and the resulting scores are used to rank the alternatives from most to least robust.

Next, vulnerability analysis applies a machine learning algorithm to accomplish two tasks (Bryant and Lempert 2010; Bonham et al. 2025). First, it identifies the streamflow statistic that is the most accurate predictor of whether a given alternative will satisfy or fail to meet a performance criterion. Second, it identifies the specific values of that statistic associated with achieving/failing the criteria. The subsequent paragraphs describe the streamflow statistics, the machine learning algorithm, and the method for evaluating accuracy.

Table E-1 below lists the streamflow statistics included in the vulnerability analysis. Each streamflow statistic is calculated for each of the 400 hydrologic futures. The statistics examine short (1-and 2-year), medium (5- and 10-year), and long-term (20-year) windows because the ability or

inability to satisfy different performance levels can be more strongly associated with different durations than others. Likewise, conditions that describe both dry and wet conditions are included because some resources are prone to failure under dry conditions (e.g., Lake Powell elevation below 3,500 feet) while others are prone to failure under wet conditions (e.g., use of Glen Canyon Dam spillway). In addition to statistics that describe dry and wet conditions, the median of the 2-, 5-, 10-, and 20-year moving average natural flows were also tested to describe "normal" conditions, which proved to be accurate predictors for several analyses important to threatened and endangered fish species (see **Figures TA 8-2** and **8-4** in **TA 8,** Biological Resources- Fish and Other Aquatic Species).

Table E-1
Streamflow statistics tested in vulnerability analysis

Streamflow Statistic	Category
Minimum 1-year natural flow volume	Dry conditions
Average Lees Ferry natural flow during the driest 2-year period	
Average Lees Ferry natural flow during the driest 5-year period	
Average Lees Ferry natural flow during the driest 10-year period	
Average Lees Ferry natural flow during the driest 20-year period	
Maximum 1-year natural flow volume	Wet conditions
Average Lees Ferry natural flow during the wettest 2-year period	
Average Lees Ferry natural flow during the wettest 5-year period	
Average Lees Ferry natural flow during the wettest 10-year period	
Average Lees Ferry natural flow during the wettest 20-year period	
Median of the moving 2-year average Lees Ferry natural flow	Normal Conditions
Median of the moving 5-year average Lees Ferry natural flow	
Median of the moving 10-year average Lees Ferry natural flow	
Median of the moving 20-year average Lees Ferry natural flow	

In this Final EIS, all streamflow statistics in **Table E-1** were considered when determining which is the most accurate predictor.

In this Final EIS, only 10-year statistics (driest 10-year period, wettest 10-year period, and median 10-year period) were considered when selecting the most accurate predictor. Because the Preferred Alternative is a 10-year decision framework, using streamflow statistics based on 10-year averages provides more relevant information than shorter or longer windows. For many resources, a streamflow statistic based on a 10-year average is the most accurate. In some cases, a 10-year statistic resulted in a small decrease in accuracy (e.g. 5-10 percent or less) compared to the best statistic (usually a 20-year statistic), but a small decrease in accuracy was deemed worth the additional relevance to the planned length of the Preferred Alternative decision framework.

The machine learning algorithm used in this analysis is a simplified version of the Patient Rule Induction Method (PRIM; Bryant and Lempert 2010). PRIM identifies values of the streamflow conditions that accurately separate the modeled futures into two categories (those that satisfied and those that failed to meet criteria). Although PRIM can test multiple streamflow statistics simultaneously, it was applied to one statistic at a time to maximize interpretability of the results.

For vulnerability analyses shown in **Volume III,** technical appendices, accuracy was evaluated with a two-step criteria. First, for each streamflow statistic, PRIM was used to identify the value such that at least 90 percent of futures that are predicted to satisfy the performance criteria actually do satisfy it (based on modeling output). Because the goal was to standardize the accuracy of results between alternatives and across resources as much as possible, the value that resulted in an accuracy closest to 90 percent was chosen[1]. This first step defines the value for each streamflow statistic and each alternative. In the second step, the streamflow statistic is selected that, on average across alternatives, has the highest accuracy at predicting a future will fail to meet the performance criteria. In the Draft EIS, all statistics in **Table ES-3** were considered, whereas this Final EIS considered only the driest, wettest, and median 10-year averages. Accuracy at predicting that a future fails the performance criteria generally ranges from 70 to 90 percent, with a limited number of exceptions that are identified with footnotes in their respective technical appendices.

For the 2027-2036 vulnerability analyses reported in **Tables ES-4** and **ES-5** in the Executive Summary, several minor changes were made to better suit a 10-year modeling period. First, because the analysis considered only the first 10 years, the only streamflow statistic evaluated was the average natural flow from 2027-2036. Second, the streamflow value that separates successful and unsuccessful futures was determined such that the value maximizes the average accuracy of predicting successful and unsuccessful futures. This approach resulted in highly accurate predictions of failure (98 percent or greater for all action alternatives)[2] and accurate predictions of success (75 percent or greater for all alternatives).

E.4 Outreach and Collaboration

DMDU is a widely accepted branch of decision science in academic research (Bonham et al 2022; Gold et al. 2022), and it has been applied in several non-academic decision support studies (Dixon and RAND Center for Terrorism Risk Management Policy 2007; Molina-Perez et al. 2019). Reclamation applied DMDU in the 2012 Colorado River Basin Water Supply and Demand Study (Reclamation 2012; Groves et al. 2013) and has funded multiple research-oriented applications investigating annual operations at Lake Powell and Lake Mead (Alexander 2018; Smith et al. 2022; Bonham et al. 2024).

This Final EIS, however, is the first use of DMDU in a decision-making process in the Colorado River Basin where numerous resources are explicitly evaluated. This is a challenge that affords tremendous opportunity for Basin-wide, cross-discipline collaboration. It was necessary for Reclamation to provide education and training so that interested parties (e.g., Basin States, tribes, partner federal agencies, the United Mexican States) could interpret results and incorporate them

[1] To standardize results as much as possible, the values of the streamflow statistics for all 400 futures were tested when evaluating accuracy. In PRIM literature, this implementation would be considered maximally "patient". The patience of the PRIM algorithm, as implemented in existing programming libraries, is controlled by the alpha parameter. To ensure all 400 futures were evaluated in this Final EIS, a custom implementation of PRIM was programmed rather than using existing programming libraries.

[2] Accuracy of predicting failures for the No Action Alternative is lower (68 percent and 86 percent for the Powell and Mead analyses, respectively). Lower accuracy is expected due to reservoir operations in the No Action Alternative being less responsive to hydrologic conditions compared to action alternatives.

into their planning activities. Further, it was necessary for Reclamation to collaborate with subject matter experts to define performance criteria. This section describes three key efforts towards achieving broader familiarity with DMDU in the Basin.

First, Reclamation developed the Integrated Technical Education Workgroup (ITEW) "to ensure that Colorado River partners have a common and accurate understanding of the underlying tools and concepts needed to meaningfully participate in the development of Post-2026 operating alternatives" (Reclamation 2023). The Research and Modeling team gave six educational and training webinars on topics including CRSS, hydrology, DMDU, and reservoir operations from May 2023 to November 2023 (www.usbr.gov/ColoradoRiverBasin/post2026). Participants included tribes, Basin States, municipalities, water and irrigation districts, non-governmental organizations, other federal agencies, researchers, and the United Mexican States.

Second, Reclamation, in partnership with Virga Labs, developed and published the "Colorado River Post-2026 Operations Exploration Tool" (hereafter "web tool"). The web tool is an interactive website (www.crbpost2026dmdu.org), launched in November 2023, that immerses the user in a guided, customizable DMDU analysis with a low barrier to entry. It is loaded with hundreds of operational strategies for Lower Basin reductions and releases from Lake Powell. The user can also create their own strategies using a variety of operational paradigms, which are then modeled in thousands of future scenarios using CRSS and cloud computing. The user defines performance requirements for the resources they are interested in, and the tool calculates robustness and vulnerability.

The web tool has been an important part of building familiarity with DMDU in the Basin. As of March 2026, 879 users have registered to use the web tool and 358 custom operational strategies have been created. It played a major role in shaping the Lower Basin shortage and Lake Powell release operations in the Maximum Operational Flexibility Alternative. Further, the tool supported extensive collaboration between Reclamation, the National Park Service, and the United States Fish and Wildlife Service to define the performance goals that shaped the Lake Powell operations in the Enhanced Coordination Alternative. Given the number of users and consistent use of the web tool for over two years, it is assumed that many others gained valuable knowledge about how to use DMDU to evaluate creative operations in the Basin.

Third, Reclamation, in partnership with AECOM, has led a major collaborative effort with resource experts to define performance thresholds and perform the DMDU analyses presented in this Final EIS. This Final EIS includes over 100 total robustness and vulnerability analyses across 17 different resources. While Reclamation has the subject matter expertise to define the performance requirements for some resource categories (e.g., water deliveries and hydrology), many resources required input from subject matter experts beyond Reclamation. The collaborative process launched in May 2024 and has required three to six meetings per resource. Participants in the collaboration include the cooperating agencies, the United States Geological Survey Grand Canyon Monitoring and Research Center, AECOM, SWCA, Hazen and Sawyer, among others (see List of Preparers, Chapter 6).

E.5 Summary

Due to the long-term planning horizon and deeply uncertain nature of hydrology, DMDU is the preferred analytical framework for the Post-2026 EIS. The main elements of DMDU, as applied in this Final EIS, are a hydrology ensemble that considers a broad range of hydrologic conditions, robustness analysis that ranks operational alternatives, and vulnerability analysis that discovers the streamflow conditions where alternatives satisfy or fail performance criteria. Reclamation has led several efforts leading up to the publication of this Final EIS to build basin-wide familiarity with DMDU, including educational webinars, an interactive web tool, and numerous collaborative meetings with resource experts. The concrete product of these efforts is the analysis contained in the technical appendices in **Volume III** of this Final EIS.

These collaborative efforts have also contributed to critical but difficult to quantify areas. This process has strengthened basin-wide, inter-agency and cross-discipline relationships. It has challenged people to grow in their understanding of the resource models this basin relies on for decision-making. And, it has created quantitative measures of performance for numerous resources where they may not have existed previously. Collectively, these "growing-pains" have paved the way for DMDU as the analytical framework used in this Final EIS, the first such multi-resource, basin-wide, decisional application in the Colorado River Basin.

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Appendix F

Approach to Hydrologic Uncertainty

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CMIP	Coupled Model Intercomparison Project
CMIP5-LOCA	Coupled Model Intercomparison Project Phase 5-Localized Constructed Analogs
CRSS	Colorado River Simulation System
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
kNN	k-Nearest Neighbors
LOCA	Localized Constructed Analogs
maf	million acre-feet
NPC	non-parametric conditioning
RCP	representative concentration pathway
Reclamation	Bureau of Reclamation
VIC	Variable Infiltration Capacity

Appendix F. Approach to Hydrologic Uncertainty

F.1 Introduction & Purpose

Future hydrology, the primary driver of how each alternative performs, is deeply uncertain over the medium-to-long-term (Smith et al. 2022). Therefore, alternatives in the Final Environmental Impact Statement (EIS) are evaluated according to how they respond to various hydrologic conditions (streamflow-conditioned analysis), their ability to maintain resource-specific performance goals across a broad range of streamflow conditions (i.e., robustness analysis) and the streamflow conditions in which each alternative is likely to fail those goals (i.e., vulnerability analysis) (McPhail et al. 2018; Bonham et al. 2024; Bonham et al. 2025; see also **Chapter 3.2.6** for information on streamflow-conditioned analysis). This approach, a type of Decision Making under Deep Uncertainty (DMDU; see **Appendix D**, DMDU Overview and Approach) (Marchau et al. 2019), requires a systematically selected set of streamflow traces to use as inputs to the resource modeling.

The modeling in the Final EIS uses 400 streamflow traces selected from a combination of five streamflow ensembles and a statistical subsampling approach. All traces from the Stress Test, Coupled Model Intercomparison Project (CMIP) Phase 5 – Localized Constructed Analogs (CMIP5-LOCA), and Drying with Variability ensembles are included (200 traces), and 200 more traces were subsampled from the Paleo Drought Resampled and CMIP Phase 3 Paleo-Conditioned ensembles using the Kennard Stone algorithm (totaling 400 traces).

The purpose of this appendix is to describe the five streamflow ensembles (**Section F.2**), explain the subsampling approach (**Section F.3**), and discuss the resulting set of 400 traces (**Section F.4**). **Section F.5** provides a summary of previous sections.

F.2 Streamflow Ensembles

F.2.1 Stress Test

The Stress Test ensemble provides continuity with many recent studies (e.g., 2019 Drought Contingency Plan) and routine long-term projections. The ensemble was created by resampling the 1988-2023[1] subset of the historical natural flow record using the index sequential method (Ouarda et al. 1997) and focusing on recent hydrology. This recent period has an 11 percent drier average flow than the full historical record (1906-2023). Use of the Stress Test ensemble is supported by multiple research studies that identified a shifting temperature trend in the Colorado River Basin in the late

[1] 2021-2023 natural flow data are estimates based on the April 2024 24-Month Study (https://www.usbr.gov/lc/region/g4000/NaturalFlow/LFnatFlow1906-2024.2024.4.22.xlsx)

1980s that affected runoff efficiency and resulted in lower average flows for the same amount of precipitation (Woodhouse et al. 2016; McCabe et al. 2017; Udall and Overpeck 2017).

F.2.2 CMIP5-LOCA

The CMIP5-LOCA ensemble uses the best available projections from global climate models that are available at the scale necessary for input to the Colorado River Simulation System (CRSS) model. The ensemble uses Upper Basin flows from a project completed by the Bureau of Reclamation's (Reclamation) Technical Services Center for the Upper and Lower Colorado Regions that relies on data from Vano et al. (2020; Reclamation 2025). These flows were created by running LOCA downscaled climate projections of temperature and precipitation through the Variable Infiltration Capacity (VIC) hydrological model. No secondary streamflow bias correction was applied to the VIC flows. The ensemble includes 64 traces: 32 traces derived from climate projections for representative concentration pathway (RCP) 4.5 and 32 traces from RCP 8.5. Natural flows for Lower Basin sites were determined by applying the k-Nearest Neighbors (kNN; Prairie et al. 2008; Nowak et al. 2010) approach, which selects flows from the historical year whose Lees Ferry flows closely match those of the projected year.

F.2.3 "Drying with Variability"

The "Drying with Variability" ensemble was developed in collaboration with Utah State University. Through a multiyear project that began in 2021, researchers performed in-depth analysis on the ensembles that were available for Reclamation's long-term modeling to identify any gaps in statistical characteristics that could (a) be important for testing the system, and (b) capture aspects of the best available information from different sources (Salehabadi et al. 2022). Analysis showed that none of the available ensembles included a long-term drying trend while maintaining or increasing variability in flow magnitudes.

As part of the project, an ensemble was developed that met these criteria using a statistical approach to combine information from multiple established data sources (Salehabadi et al. 2025). Specifically, the ensemble combines the following information:

- Observed Lees Ferry annual flows from 1931 to 2020 with wet and dry sequencing from the paleo-reconstructed record;
- An extrapolation of the observed temperature trend with an estimate of how runoff efficiency[2] is affected by warmer temperatures;
- Projections from multiple generations of global climate models that indicate that precipitation variability could increase in the future.

Through nonparametric resampling of observed flows and paleo-reconstructed sequencing, application of the long-term declining trend, and a new method for transforming the flow variability while preserving the trend, an ensemble was generated that filled the statistical and narrative gap.

[2] Runoff efficiency is a measure of the amount of streamflow produced for a given amount of precipitation. Runoff efficiency has been shown to decline as temperatures increase due to increased evaporation, drying of soils, and increased evapotranspiration from plants.

To prepare this ensemble for use in CRSS, annual Lees Ferry flows are disaggregated to all 29 natural flow locations using the kNN method (Prairie et al. 2008; Nowak et al. 2010).

The Drying-with-Variability is used as the "reference hydrology" included with every vulnerability analysis in **Volume III**. The reason this ensemble was chosen as the reference hydrology is because it helps the reader interpret the likelihood of undesirable outcomes (e.g., Lake Mead dead pool-related reductions) if the current downward trend continues and/or the frequency and duration of droughts become more severe. Given the significant decline in reservoir storage that has occurred from 2000-2025, long-term planning in the Basin must wrestle with the potential for such a future.

F.2.4 Paleo Drought Resampled (subsampled)

The Paleo Drought Resampled ensemble is a severe drought scenario developed by Salehabadi et al. (2022). The ensemble randomly resamples Lees Ferry flows from the 16th century drought (1576-1600) from Meko et al. (2017) paleo reconstruction to create 100 traces that include unique sequences of flows from this period. The ensemble was subsampled to select 50 traces that fill in patterns missing from the three complete ensembles, as described in the next section. Annual Lees Ferry flows are disaggregated to all 29 natural flow locations using the kNN method (Prairie et al. 2008; Nowak et al. 2010).

F.2.5 CMIP3 Paleo-Conditioned (subsampled)

The CMIP3 Paleo-Conditioned ensemble is developed using two valuable data sources and aligns with a recommendation from Colorado River Basin Climate and Hydrology State of the Science Report (Lukas and Payton 2020). The ensemble was created using the non-parametric conditioning (NPC) method (Prairie et al. 2008) with the Meko et al. (2017) paleo record to define wet-dry sequencing and sampled magnitudes from annual CMIP3 flows. This NPC sampling method was performed on each of the 112 CMIP3 streamflow projections (2024-2060) to create 50 traces for each projection, resulting in 5,600 traces for all 29 natural flow sites. The ensemble was subsampled to select 150 traces that fill gaps in patterns and characteristics, as described in the next section.

F.3 Subsampling Approach

The subsampling was performed using a 3-step procedure and the Kennard Stone algorithm (Kennard and Stone 1969), which, in this application, selects streamflow traces from the Paleo Drought Resampled and CMIP3 Paleo-Conditioned ensembles with statistics not well-represented by traces in the Stress Test, CMIP5-LOCA, or Drying with Variability ensembles.

This section is organized as follows. **Section F.3.1** describes the Kennard Stone algorithm. **Section F.3.2** explains the streamflow statistics used as inputs to Kennard Stone. **Section F.3.3** describes the 3-step sampling procedure.

F.3.1 Subsampling algorithm: Kennard Stone

Given an existing sample of n data points, the Kennard Stone algorithm selects k additional points (for a total of $n + k$ points) from population P such that the k points are maximally different from

the original n and from each other[3]. The algorithm uses an iterative approach; it first identifies k_1 (the first data point to be selected) as the point that maximizes the distance from all n points, where distance is calculated using statistics associated with each point and a selected distance metric. Then, k_2 is selected to maximize the distance from all n points and k_1.This process continues until all k points have been selected (Kennard and Stone 1969; Stevens and Ramirez-Lopez 2020).

In this application, each streamflow trace is a data point. The existing sample of n data points are the traces in the Stress Test, CMIP5-LOCA, and Drying with Variability ensembles (n = 36 traces [Stress Test] + 64 traces [CMIP5-LOCA] + 100 traces [Drying with Variability] = 200 traces). k = 200 so the total number of traces is 400. Mahalanobis distance (Mahalanobis 1936; Brereton 2015) was chosen for the distance metric to account for correlation between streamflow statistics, which are described in the next section.

F.3.2 Streamflow statistics

The streamflow statistics (**Table F-1**) are calculated using 2027-2056 calendar year volumes of natural flow at Lees Ferry, Arizona. The statistics describe dry, wet, and normal flow conditions over various durations (1-, 2-, 5-, 10-, and 20-year windows) to ensure the set of 400 traces cover a broad range of hydrologic conditions. The statistics are calculated for each trace of every ensemble, which are then used in the 3-step application of Kennard Stone described in **Section F.3.3**.

Table F-1
Streamflow statistics used with the Kennard Stone sampling algorithm

Streamflow Statistic	Category
Minimum 1-year natural flow volume	Dry conditions
Average Lees Ferry natural flow during the driest 5-year period	
Average Lees Ferry natural flow during the driest 10-year period	
Average Lees Ferry natural flow during the driest 20-year period	
Maximum 1-year natural flow volume	Wet conditions
Average Lees Ferry natural flow during the wettest 5-year period	
Average Lees Ferry natural flow during the wettest 10-year period	
Average Lees Ferry natural flow during the wettest 20-year period	
Median of the rolling 2-year rolling average natural flow	Normal conditions
Median of the rolling 5-year rolling average natural flow	
Median of the rolling 10-year rolling average natural flow	
Median of the rolling 20-year rolling average natural flow	
2027-2056 Average Lees Ferry natural flow	Long-term average

[3] If n = 0 (i.e., zero data points have been selected to start with), then k_1 and k_2 are selected such that they maximize the pairwise distance between any two points in the population.

F.3.3 3-Step Sampling Approach

The following 3 steps were used to subsample a total of 200 traces from the Paleo Drought Resampled and CMIP3 Paleo-Conditioned ensembles.

1. Sample 50 traces from the Paleo Drought Resampled ensemble using Kennard Stone. The 50 traces capture the variability present in this ensemble while saving computing time compared to keeping all 100 traces. This brings the total number of traces to 250.

2. Remove very wet traces from CMIP3 Paleo-Conditioned ensemble using filter criteria. This dataset contains a limited number of very wet traces because annual flows originate from the CMIP3 hydrology dataset. The goal was to systematically identify and remove these traces to avoid "shifting" the distribution of the final 400 traces wetter due to dubious high flows. To do so, the CMIP3 Paleo-Conditioned traces were compared to the maximum values for select statistics from the combined Stress Test, Paleo Drought Resampled, and Drying with Variability ensembles. If a given trace was wetter according to any of the selected statistics, then it was removed before step 3. The criteria can be expressed mathematically as:

   - maximum annual flow less than 26.45 million acre-feet (maf) & maximum 2-Year average flow less than 26.11 maf/year & maximum 5-year average flow less than 24.61 maf/year & 2027-2056 average flow less than 16.47 maf/year

   996 traces were removed because they failed one or more of the criteria, leaving 4,604 in traces in the CMIP3 Paleo-Conditioned ensemble before moving to step 3.

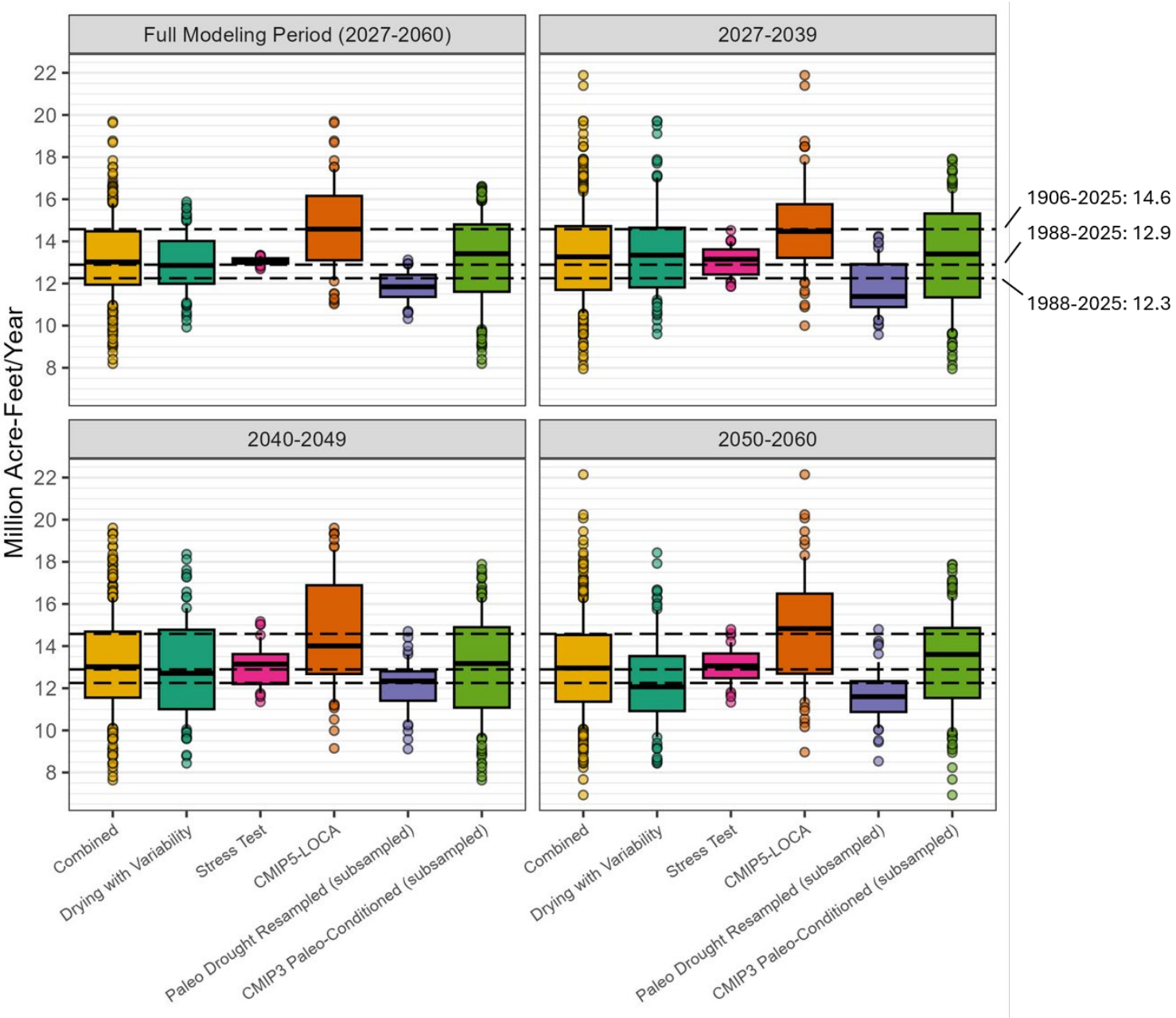
3. Sample 150 traces from the pre-filtered CMIP3 Paleo-Conditioned ensemble. This brings the total number of traces to 400.

F.4 Statistics of the 400 Hydrologic Traces

F.4.1 Decadal Average Natural Flow

Figure F-1 shows the distribution of trace average natural flow, grouped by ensemble (x-axis) and by time period (panels). All 400 traces are included in the boxplot labeled "Combined," while the remaining boxplots show traces grouped by ensemble. The time period averages are shown because the correspond to the periods used in the robustness analyses found in **Volume I – Chapter 3** and **Volume III**. For comparison, the dashed lines labelled 14.6, 13.0, and 12.4 show the historical average natural flow in maf from 1906-2025 (full historical record), 1988-2025 (Stress Test period), and 2000-2025 (Millenium Drought), respectively.

Figure F-1
Distribution of average water year natural flow at Lees Ferry, grouped by ensemble (x-axis) and by time period (panels).



Note: The dashed lines labelled 14.6, 12.9, and 12.3 indicate the historical average natural flow in maf from 1906-2025 (full historical record), 1988-2025 (Stress Test period), and 2000-2025 (Millenium Drought), respectively.

The combined set of 400 traces covers the full range of average natural flow present in any individual ensemble while providing a nearly continuous sampling from wet to dry extremes. This is important because this Final EIS evaluates critical performance goals that can fail under dry conditions (e.g. dead pool-related delivery reductions) and wet conditions (e.g. use of the Glen Canyon Dam spillway). Across the Full Modeling Period (2027-2060), average natural flow ranges from about 8.0 to 20.0 maf. Comparing the Combined boxplot to historical averages, about 50 percent of the traces are drier than the 1988-2025 average, over 25 percent of the traces are drier than the 2000-2025 average, and about 10 percent of the traces have an average below 11.0 maf/year. In the subperiods (2027-2039, 2040-2049, and 2050-2060), the 25th, 50th and 75th percentiles are similar to the Full Modeling Period while the tails of the distribution are larger in both the wet and dry direction. This is due to the averages being calculated over 10 to 13 years in the subperiods compared to the 34 years in the Full Modeling Period, which dampens the effect of extremely wet and dry years on the reported averages.

F.4.2 Average Natural Flow in 1 to 20-Year Periods

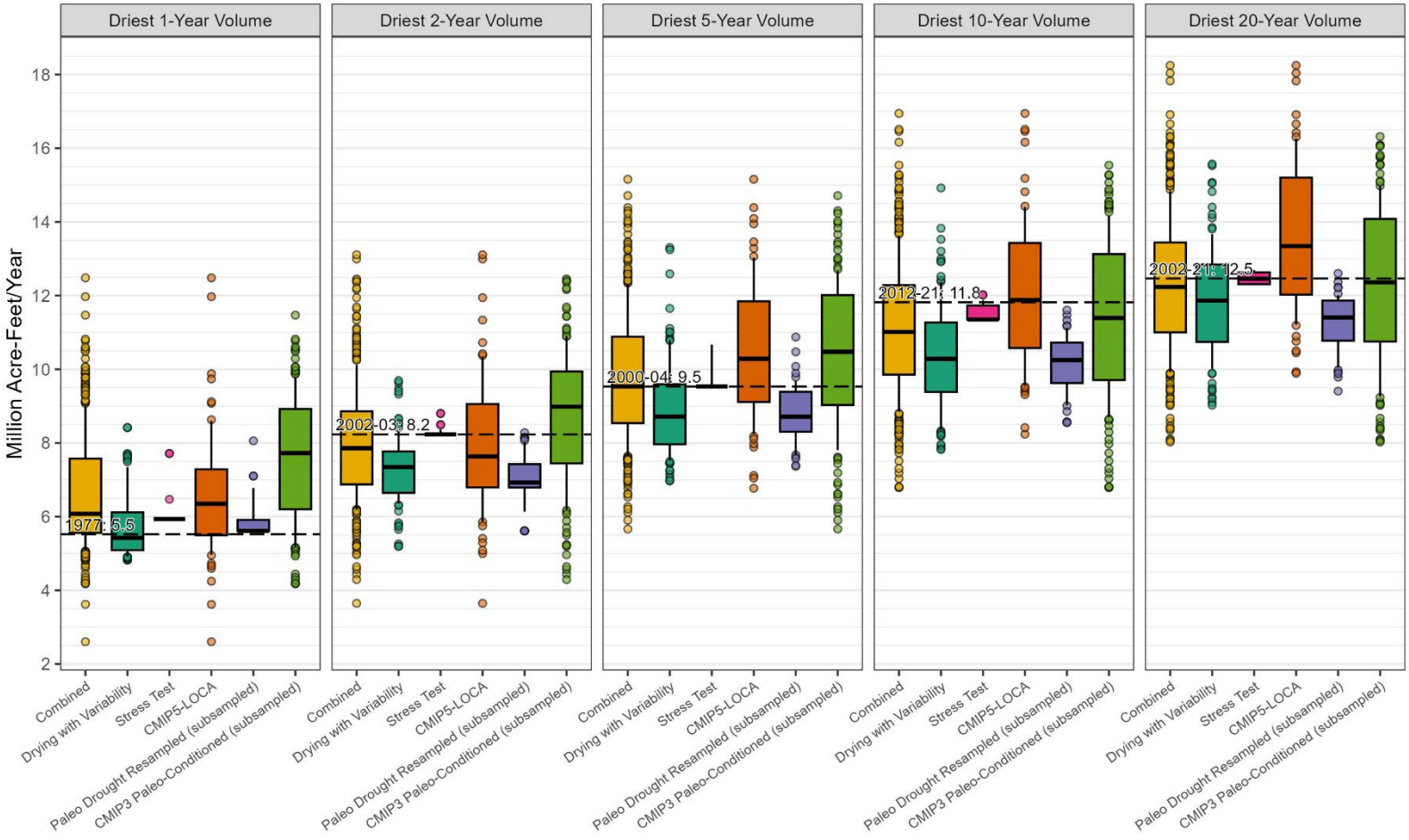
Figure F-2 shows the distribution of the driest 1-, 2-, 5-, 10-, and 20-year average volumes in each trace, grouped by ensemble. The dashed line shows the minimum volumes for each period observed during the historical period (1906-2025). In the Combined ensemble, about 25 percent of traces have a driest 1-year volume less than the historical minimum. For the 2- to 20-year trace averages, 50 percent or more of traces in the Combined ensemble are drier than the historical minimum.

Figure F-3 shows the distribution of the wettest 1-, 2-, 5-, 10-, and 20-year average volumes in each trace, grouped by ensemble. The dashed line shows the maximum volumes for each period observed during the historical period (1906-2025). Across 1-to 20-year trace averages, nearly 75 percent to over 90 percent of traces in the Combined ensemble have values less than the historical maximums.

Considering the wettest 1-year volumes, most traces above the 90th percentile in the Combined ensemble are from the CMIP5-LOCA ensemble. This is also true for the 2- to 20-year volumes, but with some of the very wet traces originating from the Drying with Variability and CMIP3 Paleo-Conditioned ensembles.

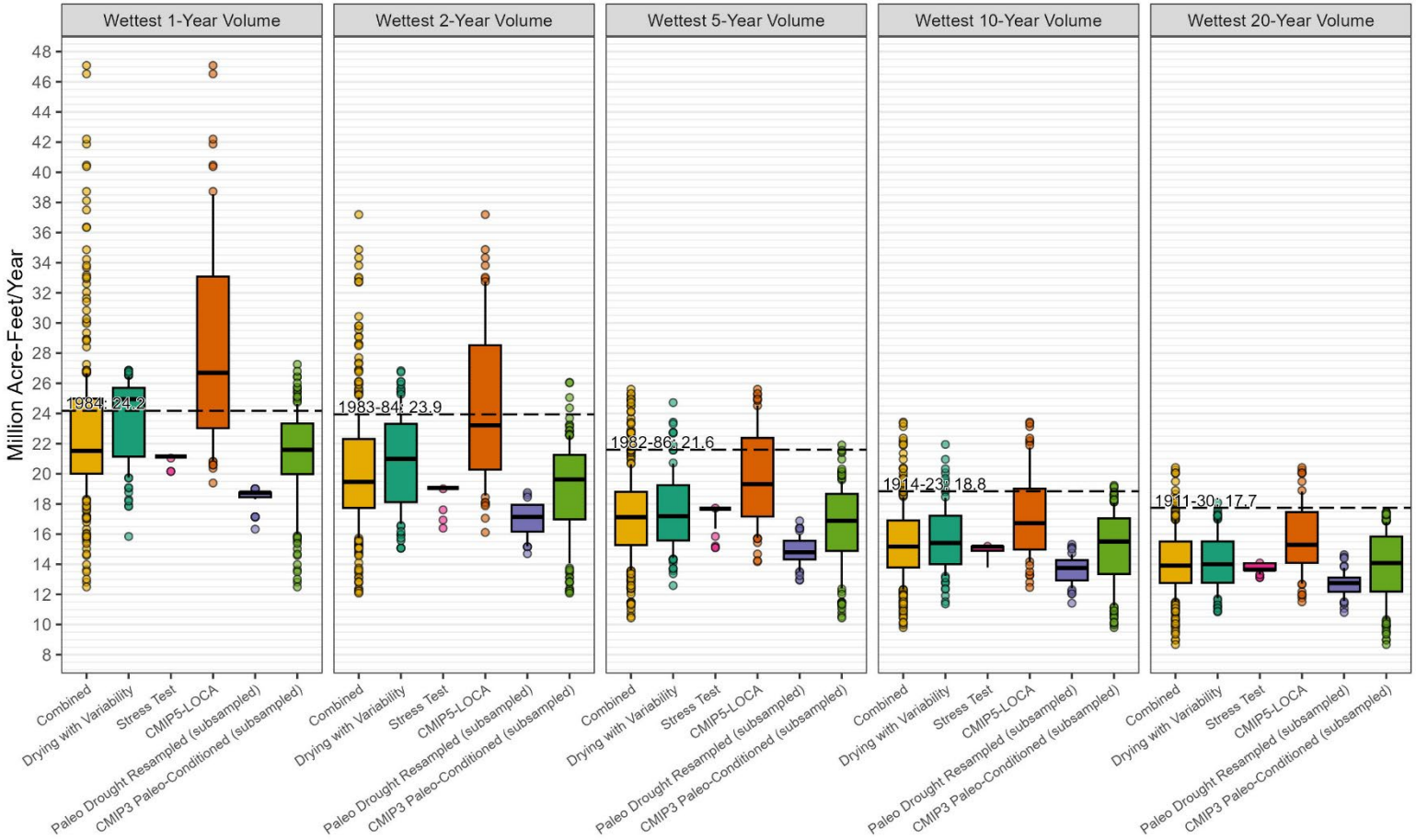
The distribution of average natural flow for the Drying with Variability ensemble, which is used as the reference hydrology in the vulnerability analysis figures in **Volume III**, demonstrates a storyline of declining streamflow over time. Over the full modeling horizon, the median average natural flow is 12.9 maf/year (slightly less than the median of the combined ensemble, 13.0 maf/year). In each subsequent subperiod, however, the median average natural flow decreases from 13.4 to 12.7 to 12.1 maf/year.

Figure F-2
Distribution of the driest 1-, 2-, 5-, 10- and 20-Water Year Volumes (columns) in each trace, grouped by ensemble.



Note: Dashed lines show the minimum volumes for each period observed during the historical period (1906-2025).

Figure F-3
Distribution of the wettest 1-, 2-, 5-, 10- and 20-Water Year Volumes (columns) in each trace, grouped by ensemble.



Note: Dashed lines show the maximum volumes for each period observed during the historical period (1906-2025).

F.4.3 Average Natural Flow Statistics Relevant to the Streamflow-Conditioned Performance Analyses

This EIS reports how system status and performance outcomes vary depending on future hydrology, termed streamflow-conditioned analysis. Two versions of streamflow-conditioned analysis were used.

Throughout the Technical Appendices in **Volume III**, streamflow-conditioned boxplots (e.g. **Figure TA 4-1**) shows how the *annual* status of the system (e.g. annual Lower Basin Shortage) changes as a function of *recent, preceding* natural flow conditions. This analysis is described in **Section F.4.3.1**, below.

Figure ES-5 in the Executive Summary shows the results of a streamflow-conditioned tradeoff analysis. This analysis reports important performance metrics (e.g. percent of time Lake Powell elevation is above 3,500 feet, percent of time Lake Mead elevation is above 975 feet) and how performance varies depending on average natural flow *over the next 10-years* (2027-2036, because the Preferred Alternative is a 10-year decision framework). This analysis is described in **Section F.4.3.2**.

F.4.3.1. Preceding 3-Year Average Flow (Streamflow-Conditioned Boxplots)

The 400 hydrologic traces are the starting point for the streamflow-conditioned boxplot analysis. Each trace is 34 years long, so there are 13,600 years of modeling results (34 years x 400 traces) per alternative. For each year, the average natural flow in the preceding 3 years is calculated. For example, in year 2030 of trace 1, the preceding 3-year average is the average of 2027-2029 in trace 1. For years 2027-2029, the preceding 3 years includes a combination of historical natural flow and natural flow associated with the low initial condition scenario[4]. A 3-year period was chosen (rather than a shorter or longer period) because experimentation demonstrated it is sufficiently long enough to capture the effects of multiple dry or wet years, while remaining short enough to reflect the influence of annual extremes.

Each of the 13,600 years is categorized based on its preceding 3-year average natural flow. The streamflow categories are Wet (greater than 16.0 maf), Moderately Wet (14.0-16.0 maf), Average (12.0-14.0 maf), Dry (10.0-12.0 maf) and Critically Dry (less than 10.0 maf). These streamflow categories were defined based on how they compare to historical conditions and stakeholders' understanding of different historical periods. A comparison of the streamflow groupings to recent historical conditions is provided in **Figure 3-1** and **Table 3-4**. Furthermore, **Figure F-4**, below, shows the 3-year average natural flow for all years in the historical record, colored by the categories used in the streamflow-conditioned boxplot analyses. The figure shows that Wet conditions (3-year average greater than 16.0 maf) were most common prior to 1931 and have not occurred since the 1990s. Since 2000, conditions have been mostly in the Average streamflow category with several years in the Moderately Wet, Dry, and Critically Dry streamflow categories.

[4] In 2027, the preceding 3 years are water years 2024, 2025, and 2026. The water year volume used for 2024 is 11.875 maf, estimated using the unregulated inflow forecast from the August 2024 24-Month Study and a regression equation to convert to natural flow (www.usbr.gov/lc/region/g4000/NaturalFlow/LFnatFlow1906-2024.2024.9.12.xlsx). See the 'documentation' sheet for the regression equation. The natural flow for 2025 and 2026 are estimated from the unregulated inflow from the November 2024 CRMMS low initial condition scenario (see **Appendix G**, CRSS Initial Conditions) and a regression equation to estimate natural flow. The estimated natural flow values are 11.1 maf (2025) and 7.0 maf (2026). The resulting 2024-2026 average is 9.99 maf, meaning that modeling results for 2027 are placed into the Critically Dry streamflow category.

Figure F-4
Historical 3-Year Average Natural Flow Colored by Streamflow Categories used in Streamflow-Conditioned Boxplot Analyses

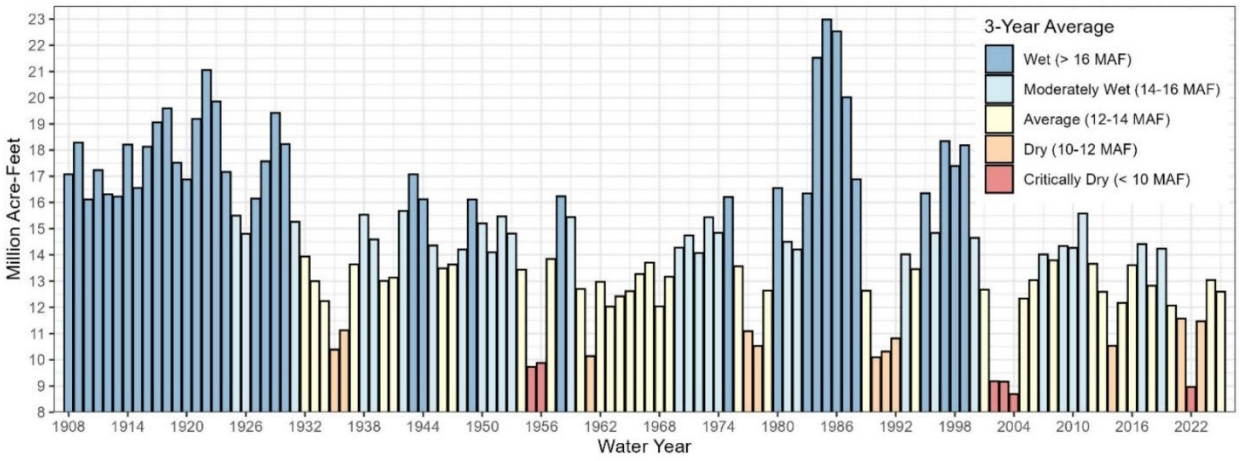
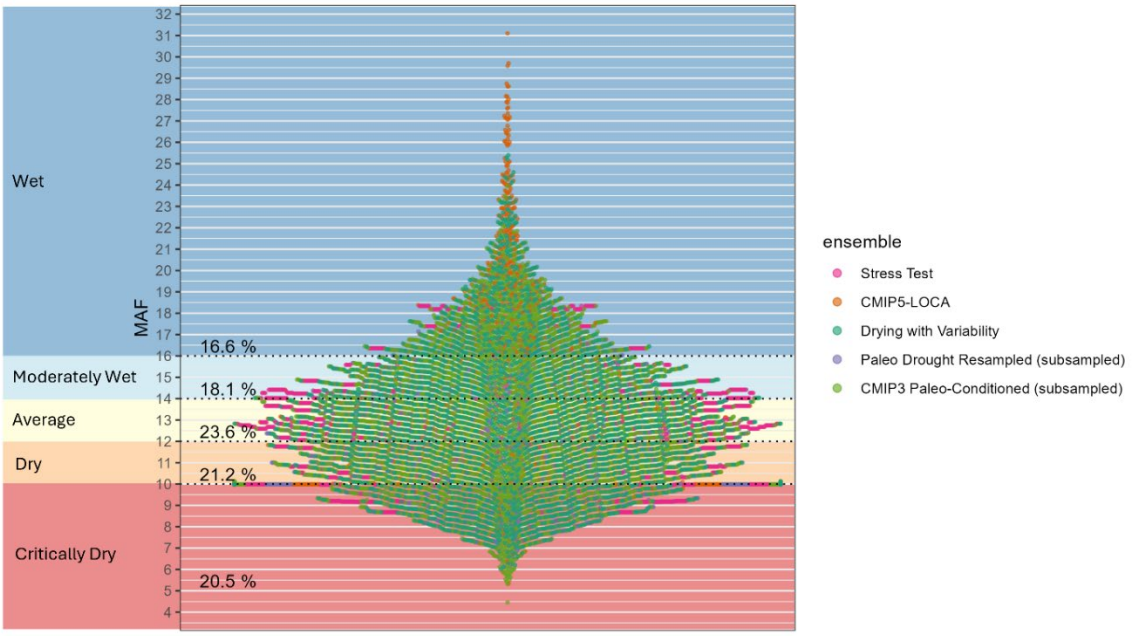


Figure F-5 shows the distribution of preceding 3-year averages across all years in the 400 hydrologic traces used in resource modeling. The streamflow categories are labeled on the left, and the percent of years in each category are reported, with 16.6 percent to 23.6 percent of years falling into each category. The wettest 3-year average is 31.1 maf (occurring in a trace from CMIP5-LOCA), and the driest 3-year average is 4.5 maf (occurring in a trace subsampled from the CMIP3 Paleo-Conditioned ensemble).

Figure F-5
Distribution of Preceding 3-Year Average Natural Flow across All Years in the 400 Hydrology Traces used for Resource Modeling



F.4.3.2. 2027-2036 Annual Average (Streamflow-Conditioned Tradeoff Analysis)

For the streamflow-conditioned tradeoff analysis presented in **Figure ES-5**, each streamflow trace (not individual years) is categorized based on the average annual natural flow in water years 2027-2036. The streamflow categories are:

- Recent 10-Year Average: 12.0-13.0 maf (68 traces)
- Driest Historical: 11.0-12.0 maf (55 traces)
- Drier than Historical: 10.0-11.0 maf (32 traces)
- Critically Dry: < 10 maf (31 traces)

Table ES-3 describes how the categories compare to recently observed 10-year averages and the driest observed 10-year average (11.8 maf from 2012-2021). Below, **Figure F-6** shows the 10-year average natural flow for all years in the historical record, colored by the categories used in the streamflow-conditioned tradeoff analysis. The figure shows that averages above 15.0 maf were most common prior to 1934 and have not occurred since 2001. 2021 and 2022 are the only years with 10-year averages below 12.0 maf. 12.0-13.0 maf 10-year averages were observed in 2023, 2024, and 2025.

Figure F-6
Distribution of Preceding 3-Year Average Natural Flow across the 400 Hydrology Traces used for Resource Modeling

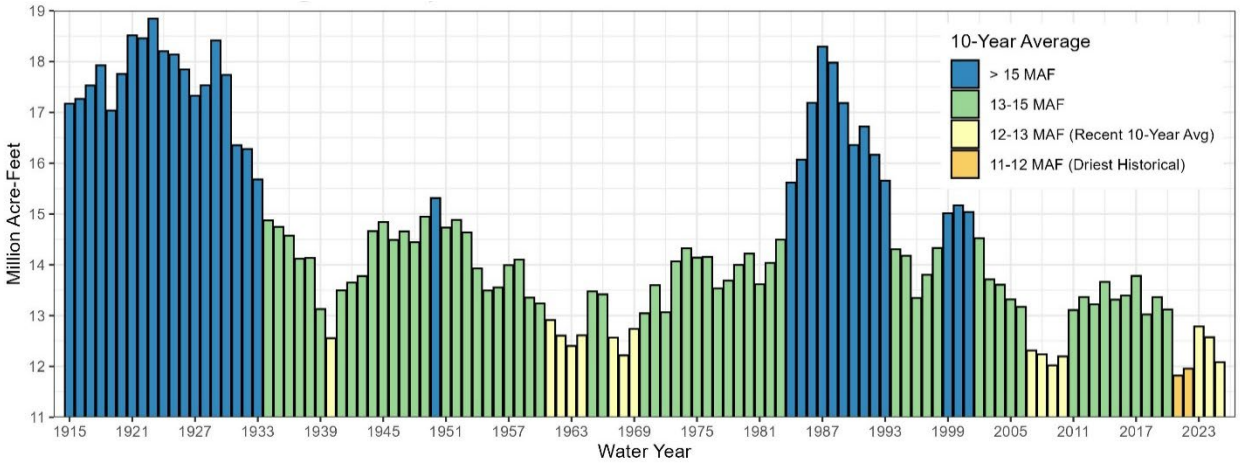
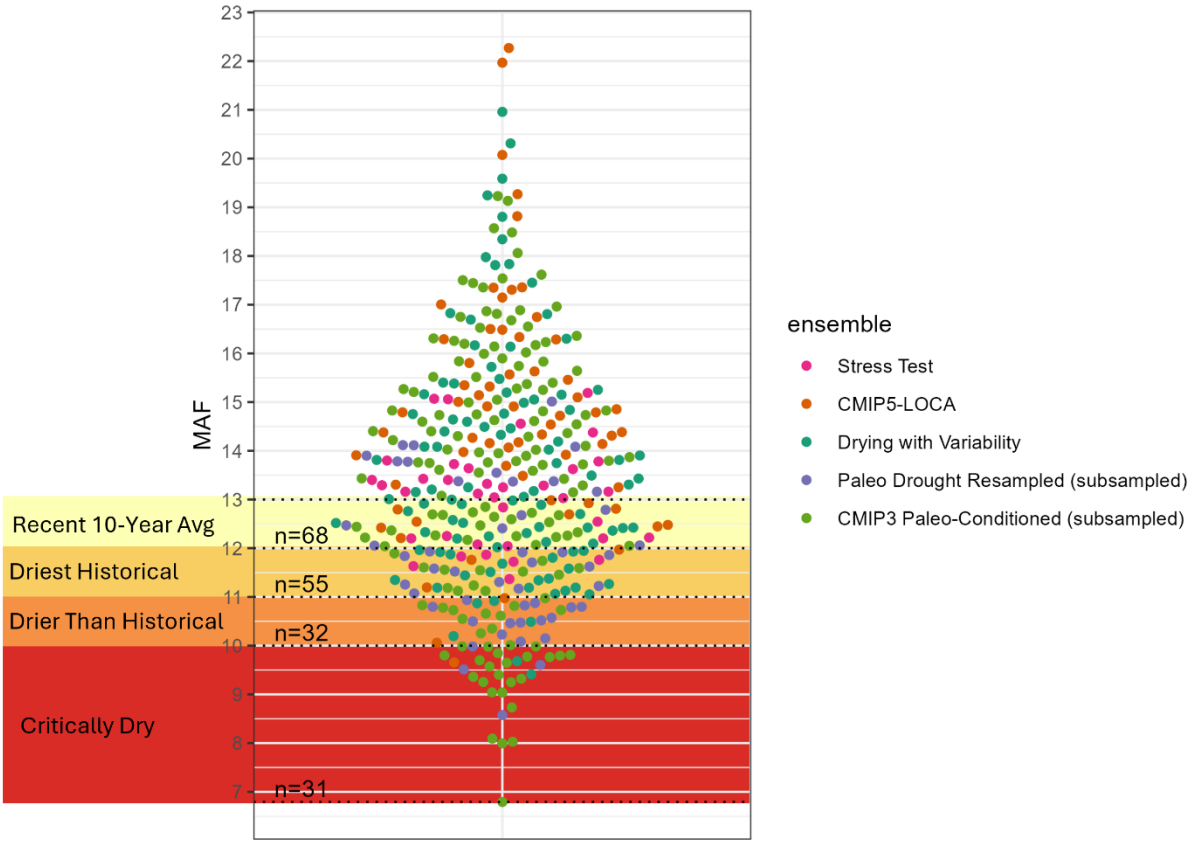


Figure F-7 shows the distribution of the 2027-2036 10-year averages across all 400 hydrologic traces used in resource modeling. The streamflow categories are labeled on the left, and the number of traces in each category are reported, with 31 to 68 traces in each category. Traces wetter than 13.0 maf were excluded from the streamflow-conditioned tradeoff analysis to focus on conditions similar to or drier than recent hydrology; doing so better demonstrates the potential impacts and tradeoffs between alternatives. The driest 2027-2036 average is 6.8 maf, occurring in a trace from the CMIP3 Paleo-Conditioned ensemble.

Figure F-7
Distribution of 2027-2036 Average Natural Flow across the 400 Hydrology Traces used for Resource Modeling



F.5 Summary

Due to the deeply uncertain nature of future hydrology in the Colorado River Basin, DMDU is the analytical framework used in this Final EIS. To reliably evaluate the robustness and vulnerability of the alternatives, it is essential to model them with a systematically selected set of streamflow traces. This Final EIS uses 400 total traces from the following ensembles:

- Stress Test (36 traces)
- CMIP5-LOCA (64 traces)
- Drying with Variability (100 traces)
- Paleo Drought Resampled (subsampled, 50 traces)
- CMIP3 Paleo-Conditioned (subsampled, 150 traces)

All traces from Stress Test, CMIP5-LOCA, and Drying with Variability ensembles were used because they provide continuity with previous analyses and useful storylines about how future

streamflow could decline. Combined, these ensembles span a wide range of plausible streamflow conditions but leave gaps in the types of conditions being evaluated. To fill in the gaps, a subsample of traces was selected from the Paleo Drought Resampled and CMIP3 Paleo-Conditioned ensembles using the Kennard Stone algorithm. The result is a combined set of 400 traces that cover a broad range of plausible conditions with minimal gaps in the types of conditions being tested.

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Appendix G

CRSS Initial Conditions

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
af	acre-feet
CRMMS	Colorado River Mid-term Modeling System
CRMMS-ESP	Colorado Basin River Forecasting Center Ensemble Streamflow Prediction
CRSS	Colorado River Simulation System
EIS	environmental impact statement
maf	million acre-feet
TMD	transmountain diversion
WY	water year

Appendix G. CRSS Initial Conditions

This appendix provides an overview of the three initial conditions used in the Final Environmental Impact Statement (EIS). It also compares these initial conditions to the June 2026 Colorado Basin River Forecasting Center Ensemble Streamflow Prediction (CRMMS-ESP) projected end-of-calendar-year (December 2026) Lake Powell and Lake Mead pool elevations to illustrate how evolving hydrologic conditions informed the selection of the initial condition used in the Final EIS analyses.

G.1 Initial Conditions Used in the Draft Environmental Impact Statement

G.1.1 Initial Reservoir Conditions

For the Final EIS, the Colorado River Simulation System (CRSS) was initialized with three sets of initial conditions to cover a range of possible system conditions on December 31, 2026. Projected system conditions were chosen from Reclamation's official mid-term operations model, the Colorado River Mid-term Modeling System (CRMMS). CRMMS uses an ensemble of monthly unregulated streamflow forecasts developed by the National Weather Service's CRMMS-ESP method.

Specifically, the CRSS modeling for the Final EIS used the November 2024[1] CRMMS-ESP projections of system conditions on December 31, 2026 as the initial conditions for CRSS. Three traces from CRMMS-ESP were selected based on Lake Powell and Lake Mead elevations and correspond to projected Low (Trace 14), Mid (Trace 12), and High (Trace 6) conditions at the end of 2026 (**Table G-1**).

Four reservoirs are not modeled in CRMMS: Strawberry, Starvation, Transmountain Diversion (TMD), and McPhee. Strawberry and Starvation Reservoirs assume a static initial condition. TMD and McPhee use a regression based on previous year's Lake Powell unregulated inflow. For all initial conditions, the December 2026 conditions for TMD and McPhee reservoirs are computed using the Mid initial condition Lake Powell unregulated inflow from CRMMS.

[1] November 2024 CRMMS projections were used as initial conditions because CRSS results for multiple alternatives were finalized in December 2024 and sent to the next stages of resource modeling needed for the Final EIS.

Table G-1
End-of-Month December 2026 Reservoir Conditions Used as Initial Conditions

Reservoir	Low (Trace 14)		Mid (Trace 12)		High (Trace 6)	
	Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
Fontenelle	6,485.00	195,027	6,486.07	201,631	6,483.49	185,892
Flaming Gorge	6,015.59	2,763,425	6,023.52	3,031,117	6,022.43	2,993,369
Strawberry	7,589.00	886,880	7,589.00	886,880	7,589.00	886,880
Starvation	5,704.82	141,791	5,704.82	141,791	5,704.82	141,791
TMD[2]	5,068.11	593,435	5,068.11	593,435	5,068.11	593,435
Taylor Park	9,294.05	47,513	9,308.16	67,009	9,308.50	67,537
Blue Mesa	7,444.41	279,616	7,477.52	484,034	7,490.00	577,661
Morrow Point	7,153.73	112,001	7,153.73	112,001	7,153.73	112,001
Crystal	6,753.04	16,970	6,753.04	16,970	6,753.04	16,970
McPhee[3]	77.10	218,374	77.10	218,374	77.10	218,374
Navajo	6,010.59	785,430	6,039.82	1,058,713	6,052.23	1,197,223
Powell	3,511.36	4,792,558	3,574.39	8,853,268	3,629.01	13,866,921
Mead	1,038.03	6,842,897	1,063.29	8,674,470	1,078.61	9,896,475
Mohave	639.51	1,604,100	639.51	1,604,100	639.51	1,604,100
Havasu	446.50	551,700	446.50	551,700	446.50	551,700

G.1.2 Preceding Lees Ferry Flows

CRSS and the Decision Making under Deep Uncertainty analysis rely on Lees Ferry natural flow for the period prior to 2026 to support various modeling assumptions and to compute hydrologic statistics. **Table G-2** summarizes Lees Ferry natural flow for water years (WY) 2017–2026. Historical natural flow estimates are available through 2024, with 2021–2024 values considered provisional. Natural flow estimates for 2025 and 2026 vary by initial condition, as they are derived from CRMMS. Since CRMMS operates in unregulated flow space, the unregulated flow is converted to natural flow using the following equation:

$$NF = (0.7311 * \mathrm{U} / 9.60 + 0.2689) * 13.49$$

Where *NF* is the WY Lees Ferry natural flow in million acre-feet (maf); *U* is the WY Lake Powell unregulated inflow in maf; 9.6 is the 1991-2020 average unregulated inflow in maf; 13.49 is the 1991-2020 average Lees Ferry Natural Flow in maf; and 0.7311 and 0.2689 are the slope and intercept of a linear regression between historical WY unregulated and natural flow at Lees Ferry using 1991-2020 data.

[2] The TMD Reservoir is an aggregate representation of Colorado western slope transmountain diversion storage facilities, including Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoir.
[3] McPhee elevation in CRSS is the height above dead pool storage.

Table G-2
Lees Ferry Water Year Natural Flow Data

Water Year	Historical Natural Flow (af)	CRMMS-Derived Lees Ferry Flow (af)		
		Low	Mid	High
2017	16,396,512	-	-	-
2018	8,633,462	-	-	-
2019	17,672,049	-	-	-
2020	9,887,593	-	-	-
2021	7,152,000	-	-	-
2022	9,851,000	-	-	-
2023	17,408,000	-	-	-
2024	11,875,000	-	-	-
2025	-	11,130,240	14,021,610	18,805,025
2026	-	6,956,534	10,888,385	12,404,377

In **Chapter 3** and **Volume III** of the Final EIS, conditional boxplots are organized according to the preceding 3-year average Lees Ferry natural flow. Because natural flows in 2025 and 2026 depend on the selected initial condition, the 3-year averages entering 2027 differ across the Low, Mid, and High initial-condition scenarios. Using the values in **Table G-2**, the resulting preceding three-year average flows and the corresponding flow category for each initial condition are shown below:

- Low initial condition: 9,987,258 acre-feet (af) (Critically Dry Flow Category [4.46–10 maf])
- Mid initial condition: 12,261,665 af (Average Flow Category [12–14 maf])
- High initial condition: 14,361,467 af (Moderately Wet Flow Category [14–16 maf])

G.2 Initial Conditions Used in the Final Environmental Impact Statement

The Colorado River system remains under significant hydrologic stress, with both Lake Powell and Lake Mead projected to reach critically low elevations in 2027 unless hydrologic conditions substantially improve. As of June 2026, WY 2026 Lake Powell unregulated inflow is projected to be approximately 3.49 maf (36 percent of average), ranking among the lowest years in the historical record. In light of current conditions, only the Low initial condition was used in the Final EIS (**Section G.1**).

G.2.1 Comparison of the Initial Conditions to the June 2026 CRMMS-ESP Projections

Figure G-1 and **Figure G-2** compare the initial conditions used in the Final EIS to the June 2026 CRMMS-ESP ensemble projections[4] for Lake Powell and Lake Mead pool elevations, respectively. The June 2026 CRMMS-ESP ensemble projects December 2026 Lake Powell pool elevations

[4] The June 2026 CRMMS-ESP projections are the most recent projections available at the time this EIS was prepared.

ranging from 3,500.01 to 3,513.07 feet. The Low initial condition falls within this projected range, while the Mid and High initial conditions exceed the upper bound of the ensemble by 61.32 and 115.94 feet, respectively.

Similarly, the June 2026 CRMMS-ESP ensemble projects December 2026 Lake Mead pool elevations ranging from 1,031.52 to 1,042.31 feet. The Low initial condition also falls within this projected range, whereas the Mid and High initial conditions exceed the upper bound of the ensemble by 20.98 and 36.30 feet, respectively.

These comparisons demonstrate that the Low initial condition used in the Final EIS is representative of current hydrologic conditions and projected end-of-calendar-year reservoir elevations. Accordingly, the Final EIS only uses the Low initial condition.

Figure G-1
Lake Powell Initial Pool Elevations: Final EIS Assumptions and Current Projections

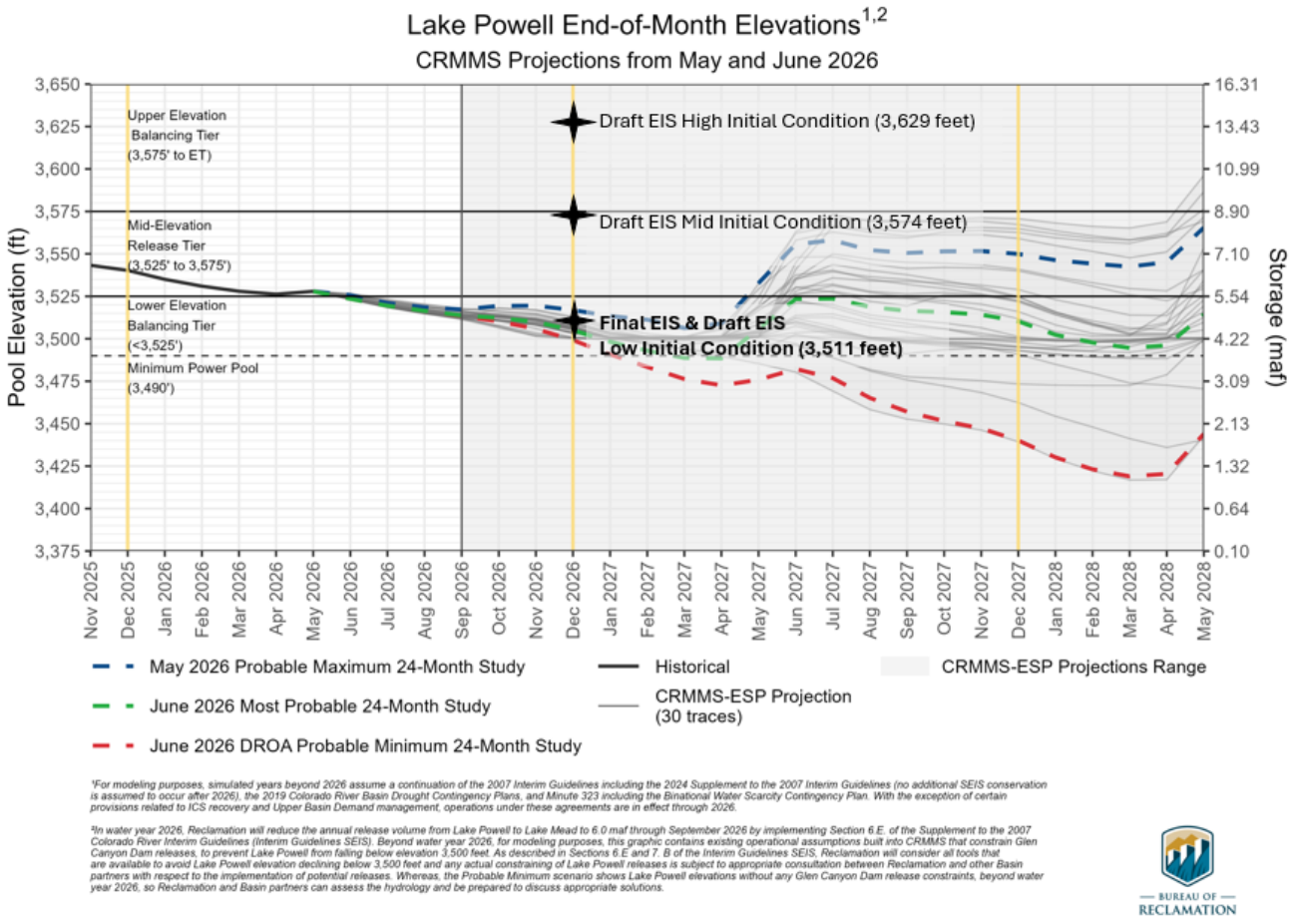
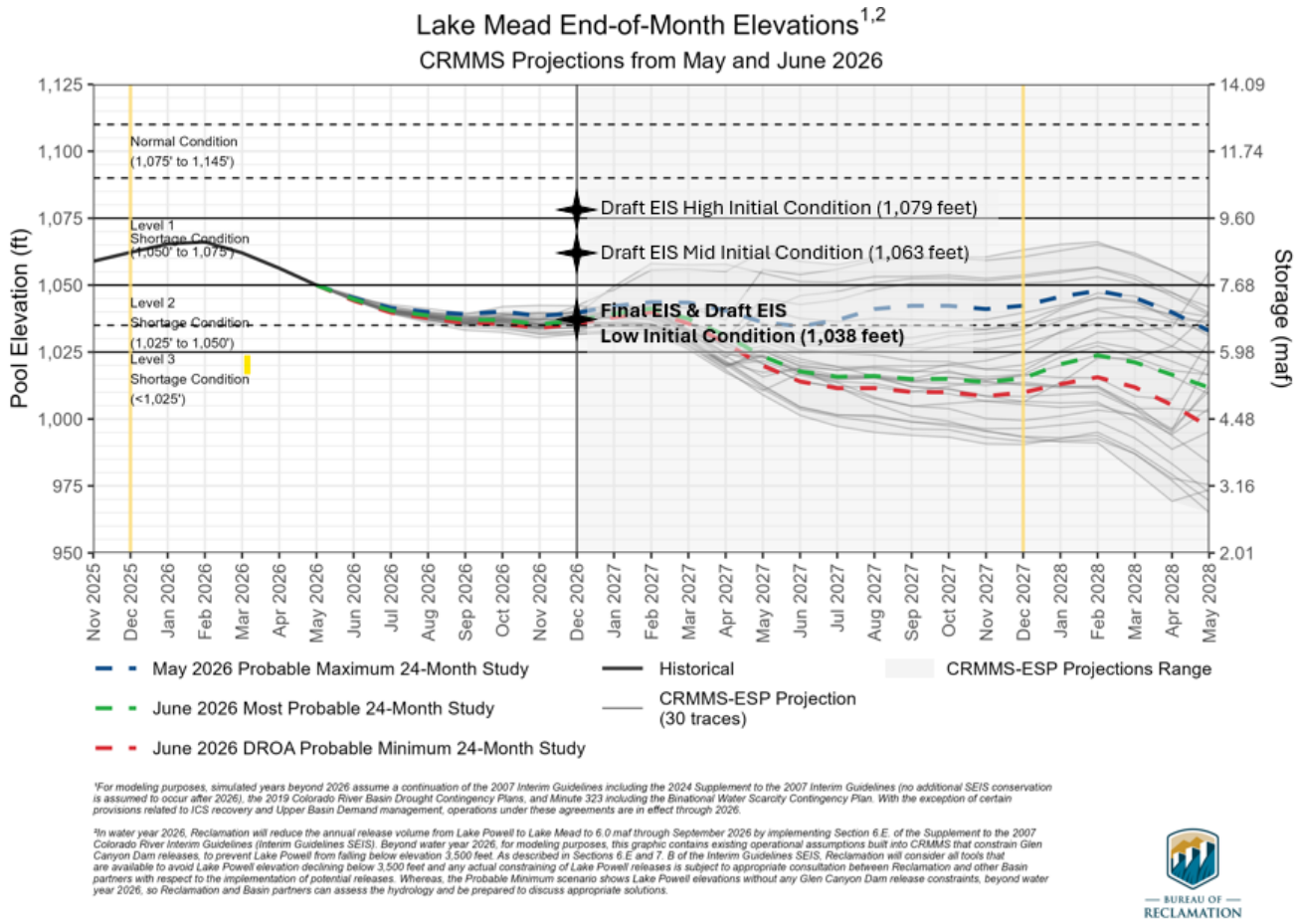


Figure G-2
Lake Mead Initial Pool Elevations: EIS Assumptions and Current Projections



[1]For modeling purposes, simulated years beyond 2026 assume a continuation of the 2007 Interim Guidelines including the 2024 Supplement to the 2007 Interim Guidelines (no additional SEIS conservation is assumed to occur after 2026), the 2019 Colorado River Basin Drought Contingency Plans, and Minute 323 including the Binational Water Scarcity Contingency Plan. With the exception of certain provisions related to ICS recovery and Upper Basin Demand management, operations under these agreements are in effect through 2026.

[2]In water year 2026, Reclamation will reduce the annual release volume from Lake Powell to Lake Mead to 6.0 maf through September 2026 by implementing Section 6.E. of the Supplement to the 2007 Colorado River Interim Guidelines (Interim Guidelines SEIS). Beyond water year 2026, for modeling purposes, this graphic contains existing operational assumptions built into CRMMS that constrain Glen Canyon Dam releases, to prevent Lake Powell from falling below elevation 3,500 feet. As described in Sections 6.E and 7. B of the Interim Guidelines SEIS, Reclamation will consider all tools that are available to avoid Lake Powell elevation declining below 3,500 feet and any actual constraining of Lake Powell releases is subject to appropriate consultation between Reclamation and other Basin partners with respect to the implementation of potential releases. Whereas, the Probable Minimum scenario shows Lake Powell elevations without any Glen Canyon Dam release constraints, beyond water year 2026, so Reclamation and Basin partners can assess the hydrology and be prepared to discuss appropriate solutions.

BUREAU OF RECLAMATION

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Appendix H

Sensitivity Analysis – Effects of Demand Schedule Assumptions on Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
EIS	environmental impact statement
maf	million acre-feet
Reclamation	United States Bureau of Reclamation
UCRC	Upper Colorado River Commission
U.S.	United States

Appendix H. Sensitivity Analysis – Effects of Demand Schedule Assumptions on Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative

H.1 Introduction

The Enhanced Coordination Alternative contemplates mechanisms to store Upper Basin unused tribal water in a Lake Powell conservation pool and Lower Basin unused tribal water in the Protection Pool in Lake Mead. The volume of unused tribal water that could be potentially available for storage in each basin is highly dependent on the modeled baseline demands and modeling assumptions developed for each storage mechanism.

This appendix summarizes the baseline demands that the United States (U.S.) Bureau of Reclamation (Reclamation) used to estimate the volumes of unused tribal water available for conservation and storage in each basin, describes the methodology for calculating these volumes, and compares potential accumulation volumes under two demand scenarios. The first scenario is based on baseline demands, which is used in the resource analysis for the Enhanced Coordination Alternative. The second scenario assumes the demands remain near historical (i.e., 2027) levels throughout the simulation period, providing an upper bound on the volume of unused tribal that could be available for storage if future demands do not increase as projected in the baseline scenario.

This appendix is exploratory and for modeling purposes only, is not intended to express any legal positions or conclusions about unused tribal water, and it does not modify any legal authorities applicable to any particular tribe's water resources. Further, nothing in this appendix represents a legal position or interpretation of any of the water rights of any basin tribes, other water users, or the Law of the River including as applicable unused water. Nothing in this appendix shall be construed so as to interpret, diminish or modify the water rights of any tribe or other water users. Reclamation continues to recognize the right of each tribe and of each of the Basin States under existing law to use and develop the water of the Colorado River System.

For purposes of this appendix, unused tribal water is defined as the difference between a quantified[1] entitlement or its depletion equivalent and the associated modeled baseline demand, subject to the following key assumptions:

- The analyzed volumes of unused tribal water are physically and legally available and deliverable for storage in Lake Powell or Lake Mead, as applicable, and can be stored in Lake Powell or Lake Mead consistent with the mechanisms explored in the Enhanced Coordination Alternative.
- In the Lower Basin, the unused tribal water analyzed in this appendix includes mainstream Lower Colorado River water entitlements.
- This appendix does not attempt to define the contours of any trust asset. Please see **Technical Appendix 18**, Indian Trust Assets, for more information on trust assets.
- The analyzed volumes of unused tribal water are derived from the entitlement-holder and do not include any analysis of possible end-user arrangements, if applicable.
- Unused tribal water is water that a tribe does not divert from the mainstream Colorado River or other applicable authorized diversion location in any given year. Unused tribal water does not include return flows or effluent.
- The term unused tribal water is used to describe when a tribe does not fully divert its quantified water entitlement, for any reason; the term does not indicate or imply that any water in the Colorado River System is left unused in any given year, as such water may be used by the other Basin, state(s), or more junior priorities consistent with existing law.
- Rounding may be used for any given entitlement.
- The Colorado River Simulation System (CRSS) requires depletion schedules to function. Tribal water entitlements may be quantified by depletion, diversion, or both, as described in the applicable legal authority. Accordingly, depletion, and/or diversion, entitlement or equivalent volumes are calculated or estimated for CRSS modeling purposes as necessary for model functionality, as described in the sections below.
- The tribal water entitlement is legally quantified, including by settlement, adjudication, or contract, with some caveats for modeling purposes as noted herein. This appendix does not attempt to quantify any currently unquantified tribal water rights.
- This appendix does not address a number of issues that may be related to implementation of any alternative, including but not limited to baseline depletion or consumptive use calculations, forbearance agreements, legal authorities, calculations related to diversion or depletion equivalents, and other operational and accounting details such as verification, water orders, and interaction with shortage distribution scheme(s).

[1] In some instances for modeling purposes, this appendix references an estimate or other data about a tribal water right. Where this occurs, it is not intended to represent a modification, alteration, or interpretation of any legal quantification and law applicable to a tribal water right. Reclamation reserves the right to update any quantifications, estimates, or data applicable to any tribal water rights as needed.

H.2 Overview of Baseline Demand Schedules

H.2.1 Upper Basin Demand Schedules

The Upper Basin CRSS baseline demand schedules were developed using data from the Upper Colorado River Commission's (UCRC) updated 2016 Depletion Demand Schedule.[2] Specifically, the UCRC—in coordination with the Upper Division States—developed decadal projections of water depletion demands by sector at the state level to support long-term planning efforts. These projections represent anticipated water demands under assumed economic and hydrologic conditions. The representation of the Upper Colorado Basin Tribes in the UCRC depletion demand schedule was presented in documentation provided by Reclamation to the Upper Colorado Basin Tribes dated July 13, 2022, that outlines the differences between the 2018 Tribal Water Study[3] demand schedules and the updated 2016 Depletion Demand Schedule. Information on how these projections are integrated into CRSS is provided in **Appendix L**, Upper Division States Depletion Schedules, with the resulting depletion schedules for the Upper Basin Tribes summarized in **Table H-1**. **Table H-1** cites the U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study (2018) as a source for certain aspects of the tribal water rights discussed herein. This citation is intended to provide an accessible source of information for the reader, and it does not supersede or modify any tribal water rights settlement or other authority. Reclamation reserves the right to update references to tribal water rights authorities in this appendix as needed and appropriate.

[2] Upper Colorado River Commission (UCRC) & Upper Division States. (2022, June 14). *Combined Resolution and Updated 2016 Depletion Demand Schedule*. Upper Colorado River Commission. Retrieved from http://www.ucrcommission.com/wp-content/uploads/2022/06/UCRC-and-Upper-Division-States-Combined-Resolution-and-Updated-2016-Depletion-Demand-Schedule-June-14-2022-1.pdf.

[3] All disclaimers in the 2018 Tribal Water Study regarding its limitations and assumption are incorporated herein by reference, including that it does not, and shall not, represent a legal position or interpretation of any of the water rights of the Partnership Tribes, by any Basin State, the federal government, or the Upper Colorado River Commission as it relates to the Law of the River. Furthermore, nothing in the Tribal Water Study is intended to, nor shall the Study be construed so as to, interpret, diminish or modify the water rights of any of the Partnership Tribes, any other tribe, any Basin State, the federal government, or the UCRC under federal or state law or administrative rule, regulation or guideline. Reclamation and the Partnership continue to recognize the right of each of the Partnership Tribes and of each of the Basin States under existing law to use and develop the water of the Colorado River System.

Table H-1
CRSS Baseline Depletion Demand Schedules for Upper Basin Tribes (acre-feet)

Year	Jicarilla (NM)	Navajo[4]				Southern Ute (CO)	Ute Indian (UT)[5]	Ute Mtn. Ute (CO)	Upper Basin Total
		(NM)	(UT)	(AZ UB)	(Total)				
2027	30,380	286,910	10,615	37,875	335,400	33,578	184,641	13,067	597,066
2028	31,020	290,040	11,896	38,400	340,336	33,912	190,157	13,131	608,556
2029	31,660	293,170	13,176	38,925	345,271	34,246	195,674	13,195	620,045
2030	32,300	296,300	14,456	39,450	350,206	34,580	201,190	13,259	631,535
2031	32,460	299,100	15,736	39,975	354,811	34,914	206,965	13,323	642,474
2032	32,620	301,900	17,017	40,500	359,417	35,248	212,741	13,387	653,413
2033	32,780	304,700	18,297	41,025	364,022	35,583	218,516	13,451	664,352
2034	32,940	307,500	19,578	41,550	368,628	35,917	224,291	13,515	675,291
2035	33,100	310,300	20,858	42,075	373,233	36,251	230,067	13,579	686,230
2036	33,260	313,100	22,138	42,600	377,838	36,585	235,842	13,643	697,168
2037	33,420	315,900	23,419	43,125	382,444	36,919	241,617	13,707	708,107
2038	33,580	318,700	24,699	43,650	387,049	37,254	247,392	13,771	719,046
2039	33,740	321,500	25,980	44,175	391,655	37,588	253,168	13,835	729,985
2040	33,900	324,300	27,260	44,700	396,260	37,922	258,943	13,899	740,924
2041	33,900	324,540	27,950	44,700	397,190	38,195	258,943	14,072	742,301
2042	33,900	324,780	28,641	44,700	398,121	38,468	258,943	14,245	743,677
2043	33,900	325,020	29,331	44,700	399,051	38,742	258,943	14,418	745,054
2044	33,900	325,260	30,021	44,700	399,981	39,015	258,943	14,591	746,430
2045	33,900	325,500	30,712	44,700	400,912	39,288	258,944	14,764	747,807
2046	33,900	325,740	31,402	44,700	401,842	39,561	258,944	14,936	749,183
2047	33,900	325,980	32,092	44,700	402,772	39,834	258,944	15,109	750,560
2048	33,900	326,220	32,782	44,700	403,702	40,108	258,944	15,282	751,936
2049	33,900	326,460	33,473	44,700	404,633	40,381	258,944	15,455	753,313
2050	33,900	326,700	34,163	44,700	405,563	40,654	258,944	15,628	754,689
2051	33,910	326,860	34,756	44,700	406,316	40,927	258,944	15,801	755,898
2052	33,920	327,020	35,350	44,700	407,070	41,200	258,944	15,974	757,107
2053	33,930	327,180	35,943	44,700	407,823	41,473	258,944	16,146	758,317

[4] The information reflected in the baseline depletion demands schedule relies on information about projected future tribal water demands. The projections were based on information compiled in a Colorado River Basin Ten Tribes Partnership Tribal Water Study (December 2018). As discussed in Chapter 8 of that Study, the technical approach was based on the best science and information available at the time, given limitations related to timeframes and resource constraints, among other things. The Navajo Nation informed Reclamation that it was developing updated projections as part of its water development planning. Reclamation worked with the Navajo Nation as needed to update demand schedules prior to the publication of the Final EIS.

[5] The Post-2026 modeling is based on water rights of the Ute Indian Tribe of the Uintah & Ouray Reservation that have not been ratified by all parties. The Ute Indian Tribe of the Uintah & Ouray Reservation has federally reserved Indian water rights, a portion of which were federally decreed in 1923 and a portion of which have been separately recognized and put to use by the U.S. and the State of Utah, which are not fully resolved. The information presented on these water rights in the Final EIS is for analysis purposes only and does not reflect a legal position or interpretation of the water rights by the U.S.

Year	Jicarilla (NM)	Navajo[4]				Southern Ute (CO)	Ute Indian (UT)[5]	Ute Mtn. Ute (CO)	Upper Basin Total
		(NM)	(UT)	(AZ UB)	(Total)				
2054	33,940	327,340	36,536	44,700	408,576	41,746	258,944	16,319	759,526
2055	33,950	327,500	37,130	44,700	409,330	42,020	258,944	16,492	760,735
2056	33,960	327,660	37,723	44,700	410,083	42,293	258,944	16,665	761,944
2057	33,970	327,820	38,316	44,700	410,836	42,566	258,944	16,838	763,153
2058	33,980	327,980	38,909	44,700	411,589	42,839	258,944	17,010	764,363
2059	33,990	328,140	39,503	44,700	412,343	43,112	258,944	17,183	765,572
2060	34,000	328,300	40,096	44,700	413,096	43,385	258,944	17,356	766,781
Diversion Entitlement/ Equivalent	45,683[6]	633,531[7]				128,939	480,590[8]		
Depletion Entitlement/ Equivalent	34,194[9]	336,979[10]	81,500[11]	47,000[12]	465,479	70,049[13]	258,944[14]	78,123[15]	928,621

H.2.2 Lower Division States Depletion Schedules

As part of the Post-2026 Environmental Impact Statement (EIS) process, the Lower Division States CRSS baseline depletion schedules were developed to ensure all water users reach their full entitlement by 2040. In general, the initial 2027 depletion is estimated as the lesser of the historical average maximum use and the user's entitlement. This estimate serves as the starting point for linear interpolation, with annual depletions gradually increasing to the full entitlement by 2040. This methodology is applied to all water users except for Metropolitan Water District, Central Arizona Project, and Southern Nevada Water Authority. For these users, the depletion is estimated by subtracting the total revised depletion schedules of all other users from the State's apportionment. The corresponding diversion is then calculated using historical average efficiency.

The depletion schedules represent the baseline demands, which are further adjusted using CRSS to account for new conservation mechanisms, Intentionally Created Surplus, shortage, surplus, and other alternative specific assumptions. A detailed description of the methodology used to develop

[6] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.4-A.
[7] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.5-B.
[8] This table includes depletion and diversion volumes from the 2009 version of the proposed Ute Indian Water Compact, which was not ratified. These volumes are intended as a placeholder for National Environmental Policy Act (NEPA) analysis purposes, may be subject to change, and are not to be construed as federal legal or policy position. See also *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.1-G.
[9] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.4-A.
[10] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.5-B.
[11] *Navajo–Utah Water Rights Settlement Act* (Pub. L. 116-260, § 1102, 2020).
[12] This table includes the depletion volume as proposed in S.953. This volume is intended as a placeholder for NEPA analysis purposes, may be subject to change, and is not to be construed as federal legal or policy position.
[13] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.2-I.
[14] This table includes depletion and diversion volumes from the 2009 version of the proposed Ute Indian Water Compact, which was not ratified. These volumes are intended as a placeholder for NEPA analysis purposes, may be subject to change, and are not to be construed as federal legal or policy position.
[15] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.3-I.

the baseline depletion schedules is provided in **Appendix M**, Lower Division States Depletion Schedules, with the resulting revised depletion schedules for the Lower Division States Tribes' mainstream entitlements summarized in **Table H-2**.

Table H-2
CRSS Baseline Depletion Schedules for Lower Division Tribes with Mainstream Entitlements[16]
(acre-feet)

Year	Chemehuevi Indian Res.	Cocopah Indian Res. (Priority 1)	Cocopah Indian Res. (Priority 4)	Colorado River Indian Res. (AZ)	Colorado River Indian Res. (CA)	Fort Mojave Indian Res. (AZ)
2027	219	5,910	31	337,116	3,322	39,174
2028	673	5,910	133	337,680	5,602	40,461
2029	1,128	5,910	235	338,244	7,883	41,748
2030	1,582	5,910	337	338,808	10,164	43,036
2031	2,036	5,910	439	339,372	12,444	44,323
2032	2,490	5,910	541	339,936	14,725	45,610
2033	2,944	5,910	643	340,500	17,006	46,898
2034	3,399	5,910	745	341,065	19,287	48,185
2035	3,853	5,910	847	341,629	21,567	49,472
2036	4,307	5,910	949	342,193	23,848	50,760
2037	4,761	5,910	1,051	342,757	26,129	52,047
2038	5,215	5,910	1,153	343,321	28,409	53,334
2039	5,669	5,910	1,255	343,885	30,690	54,622
2040-2060	6,124	5,910	1,357	344,449	32,971	55,909
Diversion Entitlement[17]	11,340	8,821	2,026	662,402	56,846	103,535
Depletion Equivalent[18]	6,124	5,910	1,357	344,449	32,971	55,909

[16] This analysis does not include the Hualapai Tribe's Arizona Priority 4 entitlement as it was acquired after the Lower Division States depletion schedules were finalized for this Final EIS.

[17] Unless otherwise noted, see the Consolidated Decree entered by the Supreme Court of the U.S. in *Arizona* v. *California*, 547 U.S. 150 (2006).

[18] CRSS requires depletion schedules; the depletion equivalent is calculated using the diversion entitlement and average historical efficiencies (2008-2022), unless otherwise noted in **Appendix M**, Lower Division States Depletion Schedules.

Table H-2 (continued)
CRSS Baseline Depletion Schedules for Lower Division Tribes with Mainstream Entitlements[19]
(acre-feet)

Year	Fort Mojave Indian Res. (CA)	Fort Mojave Indian Res. (NV)	Fort Yuma Indian Res. (AZ)	Fort Yuma Indian Res. (CA)	Hopi Tribe[20]	Indian Water Rights Settlements Priority 4[21]
2027	9,029	3,538	1,501	32,954	3,037	0
2028	9,029	3,911	2,334	32,954	3,133	269
2029	9,029	4,285	3,167	32,954	3,228	538
2030	9,029	4,659	4,001	32,954	3,324	808
2031	9,029	5,033	4,001	32,954	3,419	1,077
2032	9,029	5,407	4,001	32,954	3,515	1,346
2033	9,029	5,781	4,001	32,954	3,610	1,615
2034	9,029	6,155	4,001	32,954	3,705	1,885
2035	9,029	6,528	4,001	36,524	3,801	2,154
2036	9,029	6,902	4,001	36,524	3,896	2,423
2037	9,029	7,276	4,001	36,524	3,992	2,692
2038	9,029	7,650	4,001	36,524	4,087	2,962
2039	9,029	8,024	4,001	36,524	4,183	3,231
2040-2060	9,029	8,398	4,001	36,524	4,278	3,500
Diversion Entitlement[22]	16,720	12,534	6,350	71,616	4,278	3,500
Depletion Equivalent[23]	9,029	8,398	4,001	36,524	4,278	3,500

[19] This analysis does not include the Hualapai Tribe's Arizona Priority 4 entitlement as it was acquired after the Lower Division States depletion schedules were finalized for this Final EIS.

[20] The Hopi Tribe holds a delivery contract for an Arizona Priority 4 entitlement. This table does not include the Hopi Tribe's Arizona Priority 5 and 6 entitlements. This table is not intended to limit or preclude any future settlement terms associated with the Hopi Tribe's water resources and is not to be construed as a federal legal or policy position.

[21] This column shows the 3,500 acre-feet of Arizona Priority 4 water reserved for a Navajo-Hopi Indian water rights settlement pursuant to paragraph 11.3 of the 2007 Arizona Water Settlement Agreement as a placeholder. This table is not intended to limit or preclude any future settlement terms associated with this water and is not to be construed as a federal legal or policy position.

[22] Unless otherwise noted, see the Consolidated Decree entered by the Supreme Court of the U.S. in *Arizona* v. *California*, 547 U.S. 150 (2006).

[23] CRSS requires depletion schedules; the depletion equivalent is calculated using the diversion entitlement and average historical efficiencies (2008-2022), unless otherwise noted in **Appendix M**, Lower Division States Depletion Schedules.

H.3 Estimated Volume of Unused Tribal Water in the Baseline Demand Schedules

H.3.1 Upper Basin

Table H-3 shows the estimated unused water for the Upper Basin Tribes from 2027-2060.[24] For modeling purposes, unused water is calculated as the difference between each tribe's depletion entitlement (or depletion equivalent) (**Table H-1**) and its corresponding annual baseline depletion demand (**Table H-1**).

In the Enhanced Coordination Alternative, a portion of the total Upper Basin unused volume is assumed to be stored in the Lake Powell conservation pool each year. Additional information on the associated modeling assumptions and portion determination is provided in the following section.

Table H-3
Estimated Unused Water (Depletion) for Upper Basin Tribes (acre-feet)

Year	Jicarilla (NM)	Navajo (NM)	Navajo (UT)	Navajo (AZ UB)	Navajo (Total)	Southern Ute (CO)	Ute Indian (UT)	Ute Mountain Ute (CO)	Total
2027	3,814	50,069	70,885	9,125	130,079	36,471	74,303	65,056	309,723
2028	3,174	46,939	69,604	8,600	125,143	36,137	68,787	64,992	298,233
2029	2,534	43,809	68,324	8,075	120,208	35,803	63,270	64,928	286,744
2030	1,894	40,679	67,044	7,550	115,273	35,469	57,754	64,864	275,254
2031	1,734	37,879	65,764	7,025	110,668	35,135	51,979	64,800	264,315
2032	1,574	35,079	64,483	6,500	106,062	34,801	46,203	64,736	253,376
2033	1,414	32,279	63,203	5,975	101,457	34,466	40,428	64,672	242,437
2034	1,254	29,479	61,922	5,450	96,851	34,132	34,653	64,608	231,498
2035	1,094	26,679	60,642	4,925	92,246	33,798	28,878	64,544	220,559
2036	934	23,879	59,362	4,400	87,641	33,464	23,102	64,480	209,621
2037	774	21,079	58,081	3,875	83,035	33,130	17,327	64,416	198,682
2038	614	18,279	56,801	3,350	78,430	32,795	11,552	64,352	187,743
2039	454	15,479	55,520	2,825	73,824	32,461	5,776	64,288	176,804
2040	294	12,679	54,240	2,300	69,219	32,127	1	64,224	165,865
2041	294	12,439	53,550	2,300	68,289	31,854	1	64,051	164,488
2042	294	12,199	52,859	2,300	67,358	31,581	1	63,878	163,112
2043	294	11,959	52,169	2,300	66,428	31,307	1	63,705	161,735
2044	294	11,719	51,479	2,300	65,498	31,034	1	63,532	160,359
2045	294	11,479	50,788	2,300	64,567	30,761	0	63,359	158,982
2046	294	11,239	50,098	2,300	63,637	30,488	0	63,187	157,606

[24] This estimate is included for analysis purposes only, and it is not a limit on or prediction of actual tribal water use. Actual tribal water use may vary.

Year	Jicarilla (NM)	Navajo (NM)	Navajo (UT)	Navajo (AZ UB)	Navajo (Total)	Southern Ute (CO)	Ute Indian (UT)	Ute Mountain Ute (CO)	Total
2047	294	10,999	49,408	2,300	62,707	30,215	0	63,014	156,229
2048	294	10,759	48,718	2,300	61,777	29,941	0	62,841	154,853
2049	294	10,519	48,027	2,300	60,846	29,668	0	62,668	153,476
2050	294	10,279	47,337	2,300	59,916	29,395	0	62,495	152,100
2051	284	10,119	46,744	2,300	59,163	29,122	0	62,322	150,891
2052	274	9,959	46,150	2,300	58,409	28,849	0	62,149	149,682
2053	264	9,799	45,557	2,300	57,656	28,576	0	61,977	148,472
2054	254	9,639	44,964	2,300	56,903	28,303	0	61,804	147,263
2055	244	9,479	44,370	2,300	56,149	28,030	0	61,631	146,054
2056	234	9,319	43,777	2,300	55,396	27,756	0	61,458	144,845
2057	224	9,159	43,184	2,300	54,643	27,483	0	61,285	143,636
2058	214	8,999	42,591	2,300	53,890	27,210	0	61,113	142,426
2059	204	8,839	41,997	2,300	53,136	26,937	0	60,940	141,217
2060	194	8,679	41,404	2,300	52,383	26,664	0	60,767	140,008

H.3.2 Lower Division States

Table H-4 shows the estimated unused water for the Lower Division Tribes with mainstream entitlements from 2027-2060. All of the Lower Division Tribes with mainstream entitlements hold diversion entitlements; therefore, for modeling purposes, unused water is calculated as the difference between the depletion equivalent of each tribe's entitlement (**Table H-2**) and its corresponding annual baseline depletion schedule (**Table H-2**).

In the Enhanced Coordination Alternative, a portion of the total unused water volume from the Lower Division Tribes with mainstream entitlements is assumed to be contributed to the Protection Pool each year. These modeling assumptions are detailed in the following section.

Table H-4
Estimated Unused Water (Depletion Equivalent) for Lower Division Tribes with Mainstream Entitlements (acre-feet)

Year	Chemehuevi Indian Res.	Cocopah Indian Res. (Priority 1)	Cocopah Indian Res. (Priority 4)	Colorado River Indian Res. (AZ)	Colorado River Indian Res. (CA)	Fort Mojave Indian Res. (AZ)
2027	5,904	0	1,326	7,333	29,649	16,735
2028	5,450	0	1,224	6,769	27,368	15,448
2029	4,996	0	1,122	6,205	25,088	14,161
2030	4,542	0	1,020	5,641	22,807	12,873
2031	4,088	0	918	5,077	20,526	11,586
2032	3,633	0	816	4,513	18,246	10,299
2033	3,179	0	714	3,949	15,965	9,011
2034	2,725	0	612	3,384	13,684	7,724
2035	2,271	0	510	2,820	11,403	6,437
2036	1,817	0	408	2,256	9,123	5,149
2037	1,363	0	306	1,692	6,842	3,862
2038	908	0	204	1,128	4,561	2,575
2039	454	0	102	564	2,281	1,287
2040-2060	0	0	0	0	0	0

Table H-4 (continued)
Estimated Unused Water (Depletion Equivalent) for Lower Division States Mainstream Tribes (acre-feet)

Year	Fort Mojave Indian Res. (CA)	Fort Mojave Indian Res. (NV)	Fort Yuma Indian Res. (AZ)	Fort Yuma Indian Res. (CA)	Hopi Tribe	Indian Water Rights Settlements Priority 4	Total
2027	0	4,860	2,500	3,570	0	3,500	75,377
2028	0	4,486	1,667	3,570	0	3,231	69,213
2029	0	4,112	833	3,570	0	2,962	63,048
2030	0	3,739	0	3,570	0	2,692	56,884
2031	0	3,365	0	3,570	0	2,423	51,552
2032	0	2,991	0	3,570	0	2,154	46,221
2033	0	2,617	0	3,570	0	1,885	40,890
2034	0	2,243	0	3,570	0	1,615	35,558
2035	0	1,869	0	0	0	1,346	26,657
2036	0	1,495	0	0	0	1,077	21,325
2037	0	1,122	0	0	0	808	15,994
2038	0	748	0	0	0	538	10,663
2039	0	374	0	0	0	269	5,331
2040-2060	0	0	0	0	0	0	0

H.4 Modeled Volume of Unused Tribal Water Available for Storage

This section compares the modeled volumes of unused tribal water available for storage in Lake Powell and Lake Mead under two assumed demand schedules. As noted, only a portion of the unused tribal water, calculated using the baseline demand schedule and documented in the previous section, is assumed to be available for storage in the Enhanced Coordination Alternative. The assumptions for determining this portion are outlined below, and the resulting volume is compared to the potential volume available for storage if tribal demands remain near historical (i.e., 2027) levels.

H.4.1 Modeled Volume of Unused Tribal Water Available for Storage in Lake Powell

The Enhanced Coordination Alternative includes a Lake Powell conservation pool with a maximum capacity of 2.0 million acre-feet (maf). Both the Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool. In addition to storing Upper Basin conservation in the conservation pool, the Upper Basin Tribes could also store a portion of unused tribal water.

For modeling purposes, 5 to 15 percent of the unused Upper Basin tribal water is assumed to be available for storage in the Lake Powell conservation pool. The specific percentage, which varies with hydrologic conditions, is determined by comparing the modeled water year Lees Ferry natural flow to the 1991–2020 historical average (**Table H-5**). Linear interpolation is used to determine the specific percentage when the modeled (water year) Lees Ferry natural flow falls between 13.49 and 20.24 maf—with contributions increasing proportionally from 5 to 15 percent as natural flow increases across this range. It was assumed that this volume is contributed to the Lake Powell conservation pool without changing the inflow to Lake Powell. This operational modeling assumption implies that at least 5 to 15 percent of the unused Upper Basin tribal water physically reaches Lake Powell; however, the actual volume of unused Upper Basin tribal water that physically reaches Lake Powell is beyond the scope of this analysis.

Table H-5
Upper Basin Tribal Water Available for Storage in the Lake Powell Conservation Pool Relative to Historical Lees Ferry Natural Flow Thresholds

Current Water Year Lees Ferry Natural Flow (maf)	Annual Upper Basin Unused Tribal Contribution (%)
≥ 20.24[25]	15
Between 20.24 and 13.49[26]	5 to 15 (linear interpolation)
= 13.49	5
< 13.49	0

Table H-6 summarizes the potential volume of Upper Basin unused tribal water available for storage in the Lake Powell conservation pool.

Figure H-1 illustrates the potential cumulative contribution based on the baseline demands and the modeled natural flow used in this Final EIS analysis (see **Appendix F**, Approach to Hydrologic Uncertainty), compared to the potential cumulative contribution if the demands remain near historical (i.e., 2027) levels throughout the simulation period. In this latter scenario, the 2027 demands are assumed to remain constant through 2060.

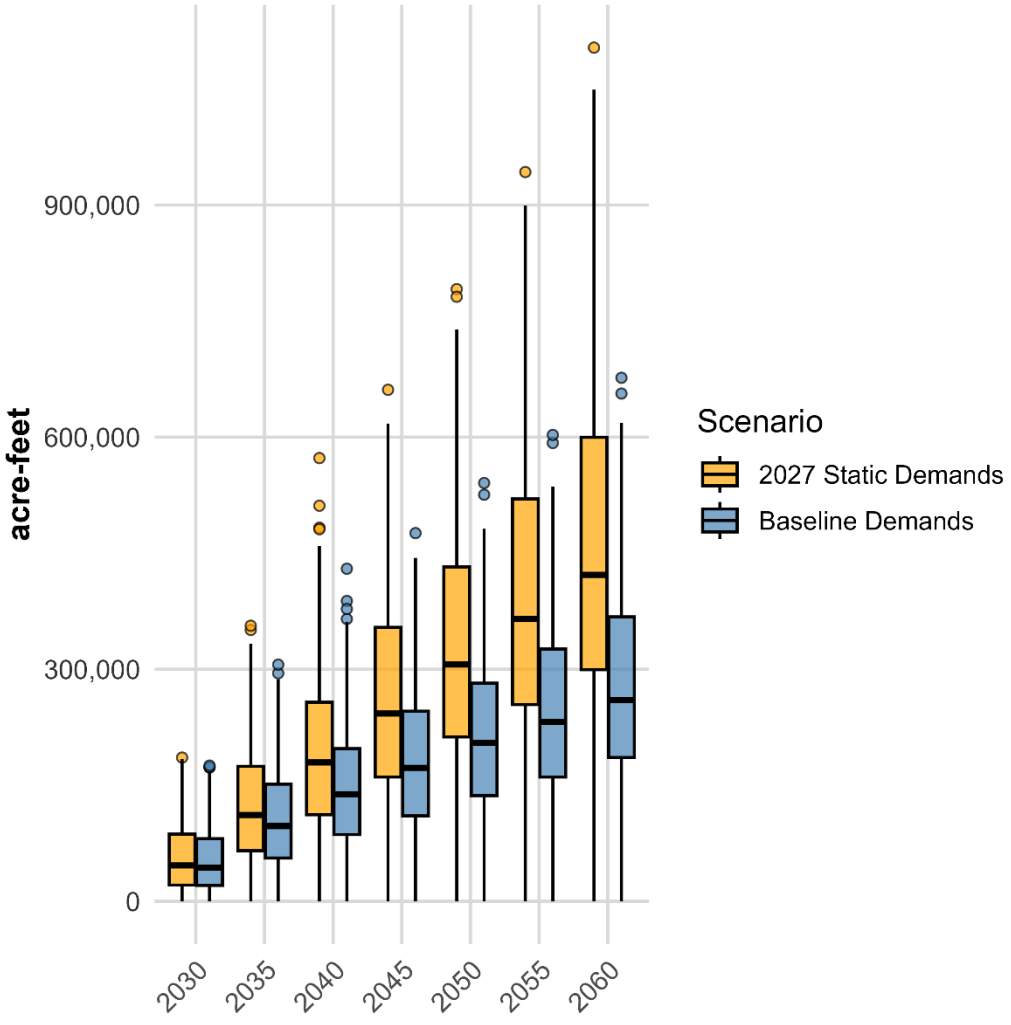
Note, the volumes shown in **Figure H-1** do not represent modeled storage of Upper Basin unused tribal water in the Lake Powell conservation pool. Stored volumes are subject to overall capacity constraints—which also account for other types of conserved water. Furthermore, water is periodically withdrawn according to the modeling assumptions detailed in the **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

[25] 150 percent of the historical average Lees Ferry natural flow from 1991-2020.
[26] Historical average Lees Ferry natural flow from 1991-2020.

Table H-6
Potential Volume of Upper Basin Unused Tribal Water Available for Storage in Lake Powell Conservation Pool (acre-feet)

Year	Potential Volume Available for Storage		
	5%	10%	15%
2027	15,486	30,972	46,458
2028	14,912	29,823	44,735
2029	14,337	28,674	43,012
2030	13,763	27,525	41,288
2031	13,216	26,432	39,647
2032	12,669	25,338	38,006
2033	12,122	24,244	36,366
2034	11,575	23,150	34,725
2035	11,028	22,056	33,084
2036	10,481	20,962	31,443
2037	9,934	19,868	29,802
2038	9,387	18,774	28,161
2039	8,840	17,680	26,521
2040	8,293	16,586	24,880
2041	8,224	16,449	24,673
2042	8,156	16,311	24,467
2043	8,087	16,174	24,260
2044	8,018	16,036	24,054
2045	7,949	15,898	23,847
2046	7,880	15,761	23,641
2047	7,811	15,623	23,434
2048	7,743	15,485	23,228
2049	7,674	15,348	23,021
2050	7,605	15,210	22,815
2051	7,545	15,089	22,634
2052	7,484	14,968	22,452
2053	7,424	14,847	22,271
2054	7,363	14,726	22,089
2055	7,303	14,605	21,908
2056	7,242	14,484	21,727
2057	7,182	14,364	21,545
2058	7,121	14,243	21,364
2059	7,061	14,122	21,183
2060	7,000	14,001	21,001

Figure H-1
Potential Cumulative Contribution from Upper Basin Unused Tribal Water



H.4.2 Estimated Modeled Volume of Unused Tribal Water Available for Storage in Lake Mead

The Enhanced Coordination Alternative includes a conservation mechanism referred to as the Protection Pool. In general, the Protection Pool is assumed to be a pool of water in Lake Mead, controlled by Reclamation for Lower Basin-wide benefits, with a maximum capacity of 2.0 maf. It is assumed that water could be acquired through multiple mechanisms, including—but not limited to—both conserved consumptive use and unused Lower Basin tribal water.

For modeling purposes, it is assumed that 10 percent of the unused Lower Basin tribal water can be stored in the Protection Pool. As a result, this water would not be available for diversion and use by lower priority water users. **Figure H-2** shows the resulting maximum potential accumulation of unused tribal water in the Protection Pool given baseline demands, compared with the maximum potential accumulation if the 2027 demands are maintained as static through 2060. The corresponding data is presented in **Table H-7**. Lower priority water users would experience a corresponding reduction in water available for their diversion and use resulting from the volume of unused water storage. Any reductions in water available to lower priority users resulting from increases to baseline demand, however, would be due to tribal water development independent of the Colorado River operations considered herein, and is not an impact of any alternatives.

Figure H-2
Maximum Potential Accumulation of Unused Tribal Water in the Protection Pool



Table H-7
Maximum Accumulation of Unused Tribal Water in the Protection Pool: Assuming 10-Percent Availability for Storage (acre-feet)

Year	Accumulated Volume	
	Baseline Demands[27]	2027 Static Demands
2027	7,538	7,538
2028	14,459	15,075
2029	20,764	22,613
2030	26,452	30,151
2031	31,607	37,689
2032	36,230	45,226
2033	40,318	52,764
2034	43,874	60,302
2035	46,540	67,840
2036	48,673	75,377
2037	50,272	82,915
2038	51,338	90,453
2039	51,871	97,991
2040	51,871	105,528
2041	51,871	113,066
2042	51,871	120,604
2043	51,871	128,142
2044	51,871	135,679
2045	51,871	143,217
2046	51,871	150,755
2047	51,871	158,293
2048	51,871	165,830
2049	51,871	173,368
2050	51,871	180,906
2051	51,871	188,444
2052	51,871	195,981
2053	51,871	203,519
2054	51,871	211,057
2055	51,871	218,595
2056	51,871	226,132
2057	51,871	233,670
2058	51,871	241,208
2059	51,871	248,746
2060	51,871	256,283

[27] The CRSS modeling erroneously includes unused tribal water associated with the Hopi Tribe. As such, the volumes here do not match 10 percent of the total in Table H-4 as they should. The maximum magnitude of the discrepancy is 868 acre-feet in 2039-2060.

Note that with the baseline demands, the maximum accumulation volume plateaus in 2040 when all users reach full use of their entitlements; in contrast, the maximum accumulation continues to linearly increase throughout the simulation period if the 2027 demands are maintained.

Additional information on the other types of water that may be stored in the Protection Pool, along with detailed modeling assumptions underlying the creation and use of Protection Pool volumes is provided in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

H.5 Summary

The Enhanced Coordination Alternative contemplates mechanisms to store Upper Basin unused tribal water in a Lake Powell conservation pool and Lower Basin unused tribal water in the Protection Pool in Lake Mead. The volume of unused tribal water available for storage in each basin is highly dependent on the assumed demand schedules and modeling assumptions developed for each storage mechanism. Stored unused tribal water would not be available for diversion and use by lower priority water users, including for some of the existing water uses of Arizona Priority 4 users (including tribes). Because of the sensitivity to these assumptions and the uncertainty associated with future demands, the volume of stored unused tribal water was evaluated using the baseline demand schedules—which generally increase over time—and compared to a scenario assuming continuation of historical demand levels.

This comparison shows that by 2060, approximately 161,933 – 426,714[28] acre-feet of additional unused tribal water could be stored in Lake Powell if Upper Basin tribal demands remain near historical levels compared to the baseline demand scenario, based on an assumed 5 to 15 percent contribution rate. As tribal demands grow over time, the volume of unused tribal water available for storage decreases correspondingly. Similarly, in the Lower Basin, approximately 204,412 acre-feet more unused tribal water could be stored in the Lake Mead Protection Pool if Lower Basin mainstream tribal demands remain near historical levels compared to the projected increases under the baseline demand scenario, based on an assumed 10 percent contribution rate. Both estimates depend on the assumed contribution rates, i.e., the portion of total unused water that can be stored.

[28] This represents the difference between the median and the maximum from **Figure H-1**, reflecting that the modeled Upper Basin volume of unused tribal water available for storage is also dependent on assumed future hydrology.

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Appendix H

Sensitivity Analysis – Effects of Demand Schedule Assumptions on Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
EIS	environmental impact statement
maf	million acre-feet
Reclamation	United States Bureau of Reclamation
UCRC	Upper Colorado River Commission
U.S.	United States

Appendix H. Sensitivity Analysis – Effects of Demand Schedule Assumptions on Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative

H.1 Introduction

The Enhanced Coordination Alternative contemplates mechanisms to store Upper Basin unused tribal water in a Lake Powell conservation pool and Lower Basin unused tribal water in the Protection Pool in Lake Mead. The volume of unused tribal water that could be potentially available for storage in each basin is highly dependent on the modeled baseline demands and modeling assumptions developed for each storage mechanism.

This appendix summarizes the baseline demands that the United States (U.S.) Bureau of Reclamation (Reclamation) used to estimate the volumes of unused tribal water available for conservation and storage in each basin, describes the methodology for calculating these volumes, and compares potential accumulation volumes under two demand scenarios. The first scenario is based on baseline demands, which is used in the resource analysis for the Enhanced Coordination Alternative. The second scenario assumes the demands remain near historical (i.e., 2027) levels throughout the simulation period, providing an upper bound on the volume of unused tribal that could be available for storage if future demands do not increase as projected in the baseline scenario.

This appendix is exploratory and for modeling purposes only, is not intended to express any legal positions or conclusions about unused tribal water, and it does not modify any legal authorities applicable to any particular tribe's water resources. Further, nothing in this appendix represents a legal position or interpretation of any of the water rights of any basin tribes, other water users, or the Law of the River including as applicable unused water. Nothing in this appendix shall be construed so as to interpret, diminish or modify the water rights of any tribe or other water users. Reclamation continues to recognize the right of each tribe and of each of the Basin States under existing law to use and develop the water of the Colorado River System.

For purposes of this appendix, unused tribal water is defined as the difference between a quantified[1] entitlement or its depletion equivalent and the associated modeled baseline demand, subject to the following key assumptions:

- The analyzed volumes of unused tribal water are physically and legally available and deliverable for storage in Lake Powell or Lake Mead, as applicable, and can be stored in Lake Powell or Lake Mead consistent with the mechanisms explored in the Enhanced Coordination Alternative.
- In the Lower Basin, the unused tribal water analyzed in this appendix includes mainstream Lower Colorado River water entitlements.
- This appendix does not attempt to define the contours of any trust asset. Please see **Technical Appendix 18**, Indian Trust Assets, for more information on trust assets.
- The analyzed volumes of unused tribal water are derived from the entitlement-holder and do not include any analysis of possible end-user arrangements, if applicable.
- Unused tribal water is water that a tribe does not divert from the mainstream Colorado River or other applicable authorized diversion location in any given year. Unused tribal water does not include return flows or effluent.
- The term unused tribal water is used to describe when a tribe does not fully divert its quantified water entitlement, for any reason; the term does not indicate or imply that any water in the Colorado River System is left unused in any given year, as such water may be used by the other Basin, state(s), or more junior priorities consistent with existing law.
- Rounding may be used for any given entitlement.
- The Colorado River Simulation System (CRSS) requires depletion schedules to function. Tribal water entitlements may be quantified by depletion, diversion, or both, as described in the applicable legal authority. Accordingly, depletion, and/or diversion, entitlement or equivalent volumes are calculated or estimated for CRSS modeling purposes as necessary for model functionality, as described in the sections below.
- The tribal water entitlement is legally quantified, including by settlement, adjudication, or contract, with some caveats for modeling purposes as noted herein. This appendix does not attempt to quantify any currently unquantified tribal water rights.
- This appendix does not address a number of issues that may be related to implementation of any alternative, including but not limited to baseline depletion or consumptive use calculations, forbearance agreements, legal authorities, calculations related to diversion or depletion equivalents, and other operational and accounting details such as verification, water orders, and interaction with shortage distribution scheme(s).

[1] In some instances for modeling purposes, this appendix references an estimate or other data about a tribal water right. Where this occurs, it is not intended to represent a modification, alteration, or interpretation of any legal quantification and law applicable to a tribal water right. Reclamation reserves the right to update any quantifications, estimates, or data applicable to any tribal water rights as needed.

H.2 Overview of Baseline Demand Schedules

H.2.1 Upper Basin Demand Schedules

The Upper Basin CRSS baseline demand schedules were developed using data from the Upper Colorado River Commission's (UCRC) updated 2016 Depletion Demand Schedule.[2] Specifically, the UCRC—in coordination with the Upper Division States—developed decadal projections of water depletion demands by sector at the state level to support long-term planning efforts. These projections represent anticipated water demands under assumed economic and hydrologic conditions. The representation of the Upper Colorado Basin Tribes in the UCRC depletion demand schedule was presented in documentation provided by Reclamation to the Upper Colorado Basin Tribes dated July 13, 2022, that outlines the differences between the 2018 Tribal Water Study[3] demand schedules and the updated 2016 Depletion Demand Schedule. Information on how these projections are integrated into CRSS is provided in **Appendix L**, Upper Division States Depletion Schedules, with the resulting depletion schedules for the Upper Basin Tribes summarized in **Table H-1**. **Table H-1** cites the U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study (2018) as a source for certain aspects of the tribal water rights discussed herein. This citation is intended to provide an accessible source of information for the reader, and it does not supersede or modify any tribal water rights settlement or other authority. Reclamation reserves the right to update references to tribal water rights authorities in this appendix as needed and appropriate.

[2] Upper Colorado River Commission (UCRC) & Upper Division States. (2022, June 14). *Combined Resolution and Updated 2016 Depletion Demand Schedule*. Upper Colorado River Commission. Retrieved from http://www.ucrcommission.com/wp-content/uploads/2022/06/UCRC-and-Upper-Division-States-Combined-Resolution-and-Updated-2016-Depletion-Demand-Schedule-June-14-2022-1.pdf.

[3] All disclaimers in the 2018 Tribal Water Study regarding its limitations and assumption are incorporated herein by reference, including that it does not, and shall not, represent a legal position or interpretation of any of the water rights of the Partnership Tribes, by any Basin State, the federal government, or the Upper Colorado River Commission as it relates to the Law of the River. Furthermore, nothing in the Tribal Water Study is intended to, nor shall the Study be construed so as to, interpret, diminish or modify the water rights of any of the Partnership Tribes, any other tribe, any Basin State, the federal government, or the UCRC under federal or state law or administrative rule, regulation or guideline. Reclamation and the Partnership continue to recognize the right of each of the Partnership Tribes and of each of the Basin States under existing law to use and develop the water of the Colorado River System.

Table H-1
CRSS Baseline Depletion Demand Schedules for Upper Basin Tribes (acre-feet)

Year	Jicarilla (NM)	Navajo[4]				Southern Ute (CO)	Ute Indian (UT)[5]	Ute Mtn. Ute (CO)	Upper Basin Total
		(NM)	(UT)	(AZ UB)	(Total)				
2027	30,380	286,910	10,615	37,875	335,400	33,578	184,641	13,067	597,066
2028	31,020	290,040	11,896	38,400	340,336	33,912	190,157	13,131	608,556
2029	31,660	293,170	13,176	38,925	345,271	34,246	195,674	13,195	620,045
2030	32,300	296,300	14,456	39,450	350,206	34,580	201,190	13,259	631,535
2031	32,460	299,100	15,736	39,975	354,811	34,914	206,965	13,323	642,474
2032	32,620	301,900	17,017	40,500	359,417	35,248	212,741	13,387	653,413
2033	32,780	304,700	18,297	41,025	364,022	35,583	218,516	13,451	664,352
2034	32,940	307,500	19,578	41,550	368,628	35,917	224,291	13,515	675,291
2035	33,100	310,300	20,858	42,075	373,233	36,251	230,067	13,579	686,230
2036	33,260	313,100	22,138	42,600	377,838	36,585	235,842	13,643	697,168
2037	33,420	315,900	23,419	43,125	382,444	36,919	241,617	13,707	708,107
2038	33,580	318,700	24,699	43,650	387,049	37,254	247,392	13,771	719,046
2039	33,740	321,500	25,980	44,175	391,655	37,588	253,168	13,835	729,985
2040	33,900	324,300	27,260	44,700	396,260	37,922	258,943	13,899	740,924
2041	33,900	324,540	27,950	44,700	397,190	38,195	258,943	14,072	742,301
2042	33,900	324,780	28,641	44,700	398,121	38,468	258,943	14,245	743,677
2043	33,900	325,020	29,331	44,700	399,051	38,742	258,943	14,418	745,054
2044	33,900	325,260	30,021	44,700	399,981	39,015	258,943	14,591	746,430
2045	33,900	325,500	30,712	44,700	400,912	39,288	258,944	14,764	747,807
2046	33,900	325,740	31,402	44,700	401,842	39,561	258,944	14,936	749,183
2047	33,900	325,980	32,092	44,700	402,772	39,834	258,944	15,109	750,560
2048	33,900	326,220	32,782	44,700	403,702	40,108	258,944	15,282	751,936
2049	33,900	326,460	33,473	44,700	404,633	40,381	258,944	15,455	753,313
2050	33,900	326,700	34,163	44,700	405,563	40,654	258,944	15,628	754,689
2051	33,910	326,860	34,756	44,700	406,316	40,927	258,944	15,801	755,898
2052	33,920	327,020	35,350	44,700	407,070	41,200	258,944	15,974	757,107
2053	33,930	327,180	35,943	44,700	407,823	41,473	258,944	16,146	758,317

[4] The information reflected in the baseline depletion demands schedule relies on information about projected future tribal water demands. The projections were based on information compiled in a Colorado River Basin Ten Tribes Partnership Tribal Water Study (December 2018). As discussed in Chapter 8 of that Study, the technical approach was based on the best science and information available at the time, given limitations related to timeframes and resource constraints, among other things. The Navajo Nation informed Reclamation that it was developing updated projections as part of its water development planning. Reclamation worked with the Navajo Nation as needed to update demand schedules prior to the publication of the Final EIS.

[5] The Post-2026 modeling is based on water rights of the Ute Indian Tribe of the Uintah & Ouray Reservation that have not been ratified by all parties. The Ute Indian Tribe of the Uintah & Ouray Reservation has federally reserved Indian water rights, a portion of which were federally decreed in 1923 and a portion of which have been separately recognized and put to use by the U.S. and the State of Utah, which are not fully resolved. The information presented on these water rights in the Final EIS is for analysis purposes only and does not reflect a legal position or interpretation of the water rights by the U.S.

Year	Jicarilla (NM)	Navajo[4]				Southern Ute (CO)	Ute Indian (UT)[5]	Ute Mtn. Ute (CO)	Upper Basin Total
		(NM)	(UT)	(AZ UB)	(Total)				
2054	33,940	327,340	36,536	44,700	408,576	41,746	258,944	16,319	759,526
2055	33,950	327,500	37,130	44,700	409,330	42,020	258,944	16,492	760,735
2056	33,960	327,660	37,723	44,700	410,083	42,293	258,944	16,665	761,944
2057	33,970	327,820	38,316	44,700	410,836	42,566	258,944	16,838	763,153
2058	33,980	327,980	38,909	44,700	411,589	42,839	258,944	17,010	764,363
2059	33,990	328,140	39,503	44,700	412,343	43,112	258,944	17,183	765,572
2060	34,000	328,300	40,096	44,700	413,096	43,385	258,944	17,356	766,781
Diversion Entitlement/ Equivalent	45,683[6]	633,531[7]				128,939	480,590[8]		
Depletion Entitlement/ Equivalent	34,194[9]	336,979[10]	81,500[11]	47,000[12]	465,479	70,049[13]	258,944[14]	78,123[15]	928,621

H.2.2 Lower Division States Depletion Schedules

As part of the Post-2026 Environmental Impact Statement (EIS) process, the Lower Division States CRSS baseline depletion schedules were developed to ensure all water users reach their full entitlement by 2040. In general, the initial 2027 depletion is estimated as the lesser of the historical average maximum use and the user's entitlement. This estimate serves as the starting point for linear interpolation, with annual depletions gradually increasing to the full entitlement by 2040. This methodology is applied to all water users except for Metropolitan Water District, Central Arizona Project, and Southern Nevada Water Authority. For these users, the depletion is estimated by subtracting the total revised depletion schedules of all other users from the State's apportionment. The corresponding diversion is then calculated using historical average efficiency.

The depletion schedules represent the baseline demands, which are further adjusted using CRSS to account for new conservation mechanisms, Intentionally Created Surplus, shortage, surplus, and other alternative specific assumptions. A detailed description of the methodology used to develop

[6] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.4-A.
[7] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.5-B.
[8] This table includes depletion and diversion volumes from the 2009 version of the proposed Ute Indian Water Compact, which was not ratified. These volumes are intended as a placeholder for National Environmental Policy Act (NEPA) analysis purposes, may be subject to change, and are not to be construed as federal legal or policy position. See also *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.1-G.
[9] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.4-A.
[10] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.5-B.
[11] *Navajo–Utah Water Rights Settlement Act* (Pub. L. 116-260, § 1102, 2020).
[12] This table includes the depletion volume as proposed in S.953. This volume is intended as a placeholder for NEPA analysis purposes, may be subject to change, and is not to be construed as federal legal or policy position.
[13] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.2-I.
[14] This table includes depletion and diversion volumes from the 2009 version of the proposed Ute Indian Water Compact, which was not ratified. These volumes are intended as a placeholder for NEPA analysis purposes, may be subject to change, and are not to be construed as federal legal or policy position.
[15] *U.S. Bureau of Reclamation and Ten Tribes Partnership, Colorado River Basin Tribal Water Study* (2018), Table 5.3-I.

the baseline depletion schedules is provided in **Appendix M**, Lower Division States Depletion Schedules, with the resulting revised depletion schedules for the Lower Division States Tribes' mainstream entitlements summarized in **Table H-2**.

Table H-2
CRSS Baseline Depletion Schedules for Lower Division Tribes with Mainstream Entitlements[16]
(acre-feet)

Year	Chemehuevi Indian Res.	Cocopah Indian Res. (Priority 1)	Cocopah Indian Res. (Priority 4)	Colorado River Indian Res. (AZ)	Colorado River Indian Res. (CA)	Fort Mojave Indian Res. (AZ)
2027	219	5,910	31	337,116	3,322	39,174
2028	673	5,910	133	337,680	5,602	40,461
2029	1,128	5,910	235	338,244	7,883	41,748
2030	1,582	5,910	337	338,808	10,164	43,036
2031	2,036	5,910	439	339,372	12,444	44,323
2032	2,490	5,910	541	339,936	14,725	45,610
2033	2,944	5,910	643	340,500	17,006	46,898
2034	3,399	5,910	745	341,065	19,287	48,185
2035	3,853	5,910	847	341,629	21,567	49,472
2036	4,307	5,910	949	342,193	23,848	50,760
2037	4,761	5,910	1,051	342,757	26,129	52,047
2038	5,215	5,910	1,153	343,321	28,409	53,334
2039	5,669	5,910	1,255	343,885	30,690	54,622
2040-2060	6,124	5,910	1,357	344,449	32,971	55,909
Diversion Entitlement[17]	11,340	8,821	2,026	662,402	56,846	103,535
Depletion Equivalent[18]	6,124	5,910	1,357	344,449	32,971	55,909

[16] This analysis does not include the Hualapai Tribe's Arizona Priority 4 entitlement as it was acquired after the Lower Division States depletion schedules were finalized for this Final EIS.

[17] Unless otherwise noted, see the Consolidated Decree entered by the Supreme Court of the U.S. in *Arizona* v. *California*, 547 U.S. 150 (2006).

[18] CRSS requires depletion schedules; the depletion equivalent is calculated using the diversion entitlement and average historical efficiencies (2008-2022), unless otherwise noted in **Appendix M**, Lower Division States Depletion Schedules.

Table H-2 (continued)
CRSS Baseline Depletion Schedules for Lower Division Tribes with Mainstream Entitlements[19]
(acre-feet)

Year	Fort Mojave Indian Res. (CA)	Fort Mojave Indian Res. (NV)	Fort Yuma Indian Res. (AZ)	Fort Yuma Indian Res. (CA)	Hopi Tribe[20]	Indian Water Rights Settlements Priority 4[21]
2027	9,029	3,538	1,501	32,954	3,037	0
2028	9,029	3,911	2,334	32,954	3,133	269
2029	9,029	4,285	3,167	32,954	3,228	538
2030	9,029	4,659	4,001	32,954	3,324	808
2031	9,029	5,033	4,001	32,954	3,419	1,077
2032	9,029	5,407	4,001	32,954	3,515	1,346
2033	9,029	5,781	4,001	32,954	3,610	1,615
2034	9,029	6,155	4,001	32,954	3,705	1,885
2035	9,029	6,528	4,001	36,524	3,801	2,154
2036	9,029	6,902	4,001	36,524	3,896	2,423
2037	9,029	7,276	4,001	36,524	3,992	2,692
2038	9,029	7,650	4,001	36,524	4,087	2,962
2039	9,029	8,024	4,001	36,524	4,183	3,231
2040-2060	9,029	8,398	4,001	36,524	4,278	3,500
Diversion Entitlement[22]	16,720	12,534	6,350	71,616	4,278	3,500
Depletion Equivalent[23]	9,029	8,398	4,001	36,524	4,278	3,500

[19] This analysis does not include the Hualapai Tribe's Arizona Priority 4 entitlement as it was acquired after the Lower Division States depletion schedules were finalized for this Final EIS.

[20] The Hopi Tribe holds a delivery contract for an Arizona Priority 4 entitlement. This table does not include the Hopi Tribe's Arizona Priority 5 and 6 entitlements. This table is not intended to limit or preclude any future settlement terms associated with the Hopi Tribe's water resources and is not to be construed as a federal legal or policy position.

[21] This column shows the 3,500 acre-feet of Arizona Priority 4 water reserved for a Navajo-Hopi Indian water rights settlement pursuant to paragraph 11.3 of the 2007 Arizona Water Settlement Agreement as a placeholder. This table is not intended to limit or preclude any future settlement terms associated with this water and is not to be construed as a federal legal or policy position.

[22] Unless otherwise noted, see the Consolidated Decree entered by the Supreme Court of the U.S. in *Arizona* v. *California*, 547 U.S. 150 (2006).

[23] CRSS requires depletion schedules; the depletion equivalent is calculated using the diversion entitlement and average historical efficiencies (2008-2022), unless otherwise noted in **Appendix M**, Lower Division States Depletion Schedules.

H.3 Estimated Volume of Unused Tribal Water in the Baseline Demand Schedules

H.3.1 Upper Basin

Table H-3 shows the estimated unused water for the Upper Basin Tribes from 2027-2060.[24] For modeling purposes, unused water is calculated as the difference between each tribe's depletion entitlement (or depletion equivalent) (**Table H-1**) and its corresponding annual baseline depletion demand (**Table H-1**).

In the Enhanced Coordination Alternative, a portion of the total Upper Basin unused volume is assumed to be stored in the Lake Powell conservation pool each year. Additional information on the associated modeling assumptions and portion determination is provided in the following section.

Table H-3
Estimated Unused Water (Depletion) for Upper Basin Tribes (acre-feet)

Year	Jicarilla (NM)	Navajo (NM)	Navajo (UT)	Navajo (AZ UB)	Navajo (Total)	Southern Ute (CO)	Ute Indian (UT)	Ute Mountain Ute (CO)	Total
2027	3,814	50,069	70,885	9,125	130,079	36,471	74,303	65,056	309,723
2028	3,174	46,939	69,604	8,600	125,143	36,137	68,787	64,992	298,233
2029	2,534	43,809	68,324	8,075	120,208	35,803	63,270	64,928	286,744
2030	1,894	40,679	67,044	7,550	115,273	35,469	57,754	64,864	275,254
2031	1,734	37,879	65,764	7,025	110,668	35,135	51,979	64,800	264,315
2032	1,574	35,079	64,483	6,500	106,062	34,801	46,203	64,736	253,376
2033	1,414	32,279	63,203	5,975	101,457	34,466	40,428	64,672	242,437
2034	1,254	29,479	61,922	5,450	96,851	34,132	34,653	64,608	231,498
2035	1,094	26,679	60,642	4,925	92,246	33,798	28,878	64,544	220,559
2036	934	23,879	59,362	4,400	87,641	33,464	23,102	64,480	209,621
2037	774	21,079	58,081	3,875	83,035	33,130	17,327	64,416	198,682
2038	614	18,279	56,801	3,350	78,430	32,795	11,552	64,352	187,743
2039	454	15,479	55,520	2,825	73,824	32,461	5,776	64,288	176,804
2040	294	12,679	54,240	2,300	69,219	32,127	1	64,224	165,865
2041	294	12,439	53,550	2,300	68,289	31,854	1	64,051	164,488
2042	294	12,199	52,859	2,300	67,358	31,581	1	63,878	163,112
2043	294	11,959	52,169	2,300	66,428	31,307	1	63,705	161,735
2044	294	11,719	51,479	2,300	65,498	31,034	1	63,532	160,359
2045	294	11,479	50,788	2,300	64,567	30,761	0	63,359	158,982
2046	294	11,239	50,098	2,300	63,637	30,488	0	63,187	157,606

[24] This estimate is included for analysis purposes only, and it is not a limit on or prediction of actual tribal water use. Actual tribal water use may vary.

Year	Jicarilla (NM)	Navajo (NM)	Navajo (UT)	Navajo (AZ UB)	Navajo (Total)	Southern Ute (CO)	Ute Indian (UT)	Ute Mountain Ute (CO)	Total
2047	294	10,999	49,408	2,300	62,707	30,215	0	63,014	156,229
2048	294	10,759	48,718	2,300	61,777	29,941	0	62,841	154,853
2049	294	10,519	48,027	2,300	60,846	29,668	0	62,668	153,476
2050	294	10,279	47,337	2,300	59,916	29,395	0	62,495	152,100
2051	284	10,119	46,744	2,300	59,163	29,122	0	62,322	150,891
2052	274	9,959	46,150	2,300	58,409	28,849	0	62,149	149,682
2053	264	9,799	45,557	2,300	57,656	28,576	0	61,977	148,472
2054	254	9,639	44,964	2,300	56,903	28,303	0	61,804	147,263
2055	244	9,479	44,370	2,300	56,149	28,030	0	61,631	146,054
2056	234	9,319	43,777	2,300	55,396	27,756	0	61,458	144,845
2057	224	9,159	43,184	2,300	54,643	27,483	0	61,285	143,636
2058	214	8,999	42,591	2,300	53,890	27,210	0	61,113	142,426
2059	204	8,839	41,997	2,300	53,136	26,937	0	60,940	141,217
2060	194	8,679	41,404	2,300	52,383	26,664	0	60,767	140,008

H.3.2 Lower Division States

Table H-4 shows the estimated unused water for the Lower Division Tribes with mainstream entitlements from 2027-2060. All of the Lower Division Tribes with mainstream entitlements hold diversion entitlements; therefore, for modeling purposes, unused water is calculated as the difference between the depletion equivalent of each tribe's entitlement (**Table H-2**) and its corresponding annual baseline depletion schedule (**Table H-2**).

In the Enhanced Coordination Alternative, a portion of the total unused water volume from the Lower Division Tribes with mainstream entitlements is assumed to be contributed to the Protection Pool each year. These modeling assumptions are detailed in the following section.

Table H-4
Estimated Unused Water (Depletion Equivalent) for Lower Division Tribes with Mainstream Entitlements (acre-feet)

Year	Chemehuevi Indian Res.	Cocopah Indian Res. (Priority 1)	Cocopah Indian Res. (Priority 4)	Colorado River Indian Res. (AZ)	Colorado River Indian Res. (CA)	Fort Mojave Indian Res. (AZ)
2027	5,904	0	1,326	7,333	29,649	16,735
2028	5,450	0	1,224	6,769	27,368	15,448
2029	4,996	0	1,122	6,205	25,088	14,161
2030	4,542	0	1,020	5,641	22,807	12,873
2031	4,088	0	918	5,077	20,526	11,586
2032	3,633	0	816	4,513	18,246	10,299
2033	3,179	0	714	3,949	15,965	9,011
2034	2,725	0	612	3,384	13,684	7,724
2035	2,271	0	510	2,820	11,403	6,437
2036	1,817	0	408	2,256	9,123	5,149
2037	1,363	0	306	1,692	6,842	3,862
2038	908	0	204	1,128	4,561	2,575
2039	454	0	102	564	2,281	1,287
2040-2060	0	0	0	0	0	0

Table H-4 (continued)
Estimated Unused Water (Depletion Equivalent) for Lower Division States Mainstream Tribes (acre-feet)

Year	Fort Mojave Indian Res. (CA)	Fort Mojave Indian Res. (NV)	Fort Yuma Indian Res. (AZ)	Fort Yuma Indian Res. (CA)	Hopi Tribe	Indian Water Rights Settlements Priority 4	Total
2027	0	4,860	2,500	3,570	0	3,500	75,377
2028	0	4,486	1,667	3,570	0	3,231	69,213
2029	0	4,112	833	3,570	0	2,962	63,048
2030	0	3,739	0	3,570	0	2,692	56,884
2031	0	3,365	0	3,570	0	2,423	51,552
2032	0	2,991	0	3,570	0	2,154	46,221
2033	0	2,617	0	3,570	0	1,885	40,890
2034	0	2,243	0	3,570	0	1,615	35,558
2035	0	1,869	0	0	0	1,346	26,657
2036	0	1,495	0	0	0	1,077	21,325
2037	0	1,122	0	0	0	808	15,994
2038	0	748	0	0	0	538	10,663
2039	0	374	0	0	0	269	5,331
2040-2060	0	0	0	0	0	0	0

H.4 Modeled Volume of Unused Tribal Water Available for Storage

This section compares the modeled volumes of unused tribal water available for storage in Lake Powell and Lake Mead under two assumed demand schedules. As noted, only a portion of the unused tribal water, calculated using the baseline demand schedule and documented in the previous section, is assumed to be available for storage in the Enhanced Coordination Alternative. The assumptions for determining this portion are outlined below, and the resulting volume is compared to the potential volume available for storage if tribal demands remain near historical (i.e., 2027) levels.

H.4.1 Modeled Volume of Unused Tribal Water Available for Storage in Lake Powell

The Enhanced Coordination Alternative includes a Lake Powell conservation pool with a maximum capacity of 2.0 million acre-feet (maf). Both the Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool. In addition to storing Upper Basin conservation in the conservation pool, the Upper Basin Tribes could also store a portion of unused tribal water.

For modeling purposes, 5 to 15 percent of the unused Upper Basin tribal water is assumed to be available for storage in the Lake Powell conservation pool. The specific percentage, which varies with hydrologic conditions, is determined by comparing the modeled water year Lees Ferry natural flow to the 1991–2020 historical average (**Table H-5**). Linear interpolation is used to determine the specific percentage when the modeled (water year) Lees Ferry natural flow falls between 13.49 and 20.24 maf—with contributions increasing proportionally from 5 to 15 percent as natural flow increases across this range. It was assumed that this volume is contributed to the Lake Powell conservation pool without changing the inflow to Lake Powell. This operational modeling assumption implies that at least 5 to 15 percent of the unused Upper Basin tribal water physically reaches Lake Powell; however, the actual volume of unused Upper Basin tribal water that physically reaches Lake Powell is beyond the scope of this analysis.

Table H-5
Upper Basin Tribal Water Available for Storage in the Lake Powell Conservation Pool Relative to Historical Lees Ferry Natural Flow Thresholds

Current Water Year Lees Ferry Natural Flow (maf)	Annual Upper Basin Unused Tribal Contribution (%)
≥ 20.24[25]	15
Between 20.24 and 13.49[26]	5 to 15 (linear interpolation)
= 13.49	5
< 13.49	0

Table H-6 summarizes the potential volume of Upper Basin unused tribal water available for storage in the Lake Powell conservation pool.

Figure H-1 illustrates the potential cumulative contribution based on the baseline demands and the modeled natural flow used in this Final EIS analysis (see **Appendix F**, Approach to Hydrologic Uncertainty), compared to the potential cumulative contribution if the demands remain near historical (i.e., 2027) levels throughout the simulation period. In this latter scenario, the 2027 demands are assumed to remain constant through 2060.

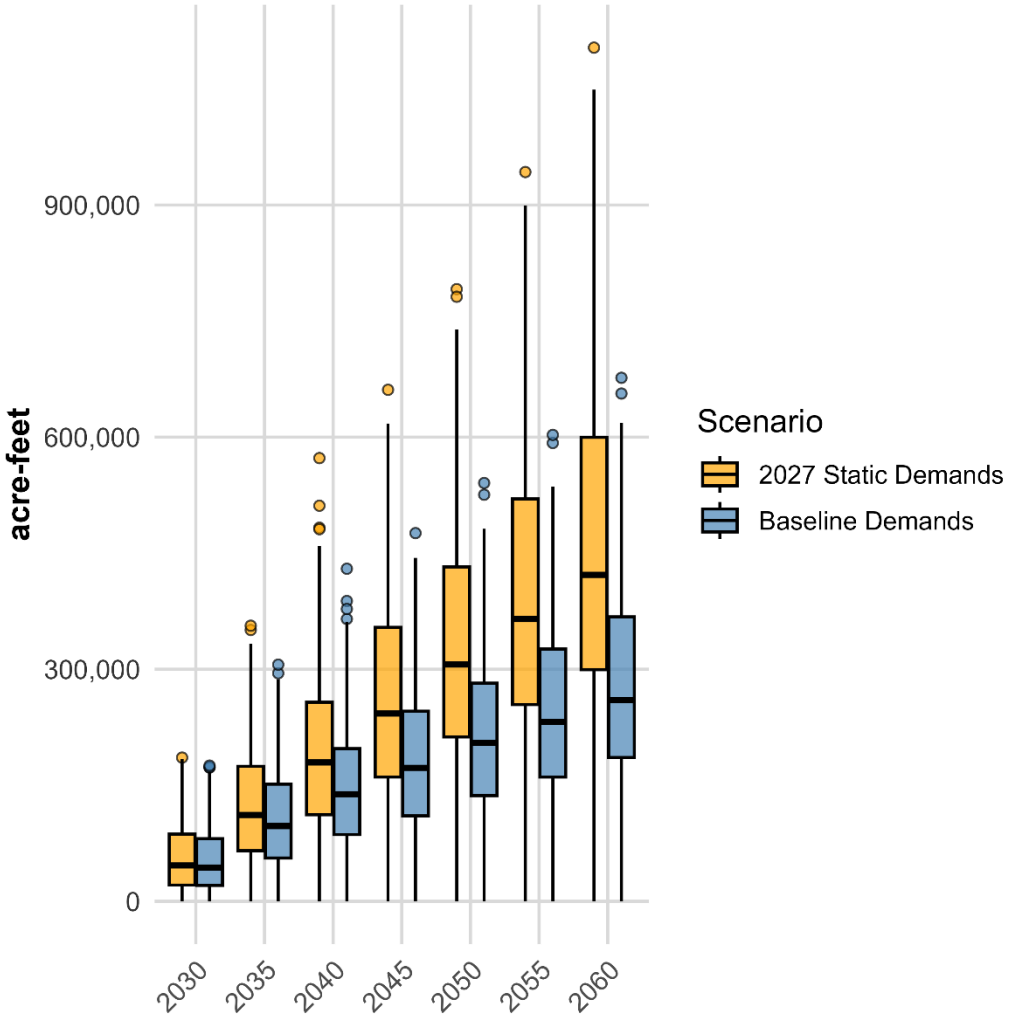
Note, the volumes shown in **Figure H-1** do not represent modeled storage of Upper Basin unused tribal water in the Lake Powell conservation pool. Stored volumes are subject to overall capacity constraints—which also account for other types of conserved water. Furthermore, water is periodically withdrawn according to the modeling assumptions detailed in the **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

[25] 150 percent of the historical average Lees Ferry natural flow from 1991-2020.
[26] Historical average Lees Ferry natural flow from 1991-2020.

Table H-6
Potential Volume of Upper Basin Unused Tribal Water Available for Storage in Lake Powell Conservation Pool (acre-feet)

Year	Potential Volume Available for Storage		
	5%	10%	15%
2027	15,486	30,972	46,458
2028	14,912	29,823	44,735
2029	14,337	28,674	43,012
2030	13,763	27,525	41,288
2031	13,216	26,432	39,647
2032	12,669	25,338	38,006
2033	12,122	24,244	36,366
2034	11,575	23,150	34,725
2035	11,028	22,056	33,084
2036	10,481	20,962	31,443
2037	9,934	19,868	29,802
2038	9,387	18,774	28,161
2039	8,840	17,680	26,521
2040	8,293	16,586	24,880
2041	8,224	16,449	24,673
2042	8,156	16,311	24,467
2043	8,087	16,174	24,260
2044	8,018	16,036	24,054
2045	7,949	15,898	23,847
2046	7,880	15,761	23,641
2047	7,811	15,623	23,434
2048	7,743	15,485	23,228
2049	7,674	15,348	23,021
2050	7,605	15,210	22,815
2051	7,545	15,089	22,634
2052	7,484	14,968	22,452
2053	7,424	14,847	22,271
2054	7,363	14,726	22,089
2055	7,303	14,605	21,908
2056	7,242	14,484	21,727
2057	7,182	14,364	21,545
2058	7,121	14,243	21,364
2059	7,061	14,122	21,183
2060	7,000	14,001	21,001

Figure H-1
Potential Cumulative Contribution from Upper Basin Unused Tribal Water



H.4.2 Estimated Modeled Volume of Unused Tribal Water Available for Storage in Lake Mead

The Enhanced Coordination Alternative includes a conservation mechanism referred to as the Protection Pool. In general, the Protection Pool is assumed to be a pool of water in Lake Mead, controlled by Reclamation for Lower Basin-wide benefits, with a maximum capacity of 2.0 maf. It is assumed that water could be acquired through multiple mechanisms, including—but not limited to—both conserved consumptive use and unused Lower Basin tribal water.

For modeling purposes, it is assumed that 10 percent of the unused Lower Basin tribal water can be stored in the Protection Pool. As a result, this water would not be available for diversion and use by lower priority water users. **Figure H-2** shows the resulting maximum potential accumulation of unused tribal water in the Protection Pool given baseline demands, compared with the maximum potential accumulation if the 2027 demands are maintained as static through 2060. The corresponding data is presented in **Table H-7**. Lower priority water users would experience a corresponding reduction in water available for their diversion and use resulting from the volume of unused water storage. Any reductions in water available to lower priority users resulting from increases to baseline demand, however, would be due to tribal water development independent of the Colorado River operations considered herein, and is not an impact of any alternatives.

Figure H-2
Maximum Potential Accumulation of Unused Tribal Water in the Protection Pool



Table H-7
Maximum Accumulation of Unused Tribal Water in the Protection Pool: Assuming 10-Percent Availability for Storage (acre-feet)

Year	Accumulated Volume	
	Baseline Demands[27]	2027 Static Demands
2027	7,538	7,538
2028	14,459	15,075
2029	20,764	22,613
2030	26,452	30,151
2031	31,607	37,689
2032	36,230	45,226
2033	40,318	52,764
2034	43,874	60,302
2035	46,540	67,840
2036	48,673	75,377
2037	50,272	82,915
2038	51,338	90,453
2039	51,871	97,991
2040	51,871	105,528
2041	51,871	113,066
2042	51,871	120,604
2043	51,871	128,142
2044	51,871	135,679
2045	51,871	143,217
2046	51,871	150,755
2047	51,871	158,293
2048	51,871	165,830
2049	51,871	173,368
2050	51,871	180,906
2051	51,871	188,444
2052	51,871	195,981
2053	51,871	203,519
2054	51,871	211,057
2055	51,871	218,595
2056	51,871	226,132
2057	51,871	233,670
2058	51,871	241,208
2059	51,871	248,746
2060	51,871	256,283

[27] The CRSS modeling erroneously includes unused tribal water associated with the Hopi Tribe. As such, the volumes here do not match 10 percent of the total in Table H-4 as they should. The maximum magnitude of the discrepancy is 868 acre-feet in 2039-2060.

Note that with the baseline demands, the maximum accumulation volume plateaus in 2040 when all users reach full use of their entitlements; in contrast, the maximum accumulation continues to linearly increase throughout the simulation period if the 2027 demands are maintained.

Additional information on the other types of water that may be stored in the Protection Pool, along with detailed modeling assumptions underlying the creation and use of Protection Pool volumes is provided in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

H.5 Summary

The Enhanced Coordination Alternative contemplates mechanisms to store Upper Basin unused tribal water in a Lake Powell conservation pool and Lower Basin unused tribal water in the Protection Pool in Lake Mead. The volume of unused tribal water available for storage in each basin is highly dependent on the assumed demand schedules and modeling assumptions developed for each storage mechanism. Stored unused tribal water would not be available for diversion and use by lower priority water users, including for some of the existing water uses of Arizona Priority 4 users (including tribes). Because of the sensitivity to these assumptions and the uncertainty associated with future demands, the volume of stored unused tribal water was evaluated using the baseline demand schedules—which generally increase over time—and compared to a scenario assuming continuation of historical demand levels.

This comparison shows that by 2060, approximately 161,933 – 426,714[28] acre-feet of additional unused tribal water could be stored in Lake Powell if Upper Basin tribal demands remain near historical levels compared to the baseline demand scenario, based on an assumed 5 to 15 percent contribution rate. As tribal demands grow over time, the volume of unused tribal water available for storage decreases correspondingly. Similarly, in the Lower Basin, approximately 204,412 acre-feet more unused tribal water could be stored in the Lake Mead Protection Pool if Lower Basin mainstream tribal demands remain near historical levels compared to the projected increases under the baseline demand scenario, based on an assumed 10 percent contribution rate. Both estimates depend on the assumed contribution rates, i.e., the portion of total unused water that can be stored.

[28] This represents the difference between the median and the maximum from **Figure H-1**, reflecting that the modeled Upper Basin volume of unused tribal water available for storage is also dependent on assumed future hydrology.

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Appendix I

Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2016 UCRC	Upper Colorado River Commission Updated 2016 Depletion Demand Schedule
CCS	Continued Current Strategies
CRSS	Colorado River Simulation System
CU&L	consumptive use and loss
DMDU	Decision Making Under Deep Uncertainty
EIS	environmental impact statement
EOCY	end of calendar year
EOWY	end of water year
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
maf	million acre-feet
Mexico	United Mexican States
PIP	Powell Infrastructure Protection
Reclamation	Bureau of Reclamation

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Appendix I. Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead

I.1 Introduction

Future water depletion demands are required inputs to the Colorado River Simulation System (CRSS) and are one of the key future uncertainties for which assumptions must be developed. This appendix presents a sensitivity analysis that evaluates how future depletion demand assumptions influence modeled system conditions and vulnerabilities. Because of hydrologic and institutional differences between the Upper and Lower Basins, scenarios are treated differently for each basin.

In the Upper Basin, hydrology varies significantly both geographically and from year to year, resulting in shortages when the available supply is insufficient to meet demands. Because water users are subject to this hydrologic variability and the Upper Basin is currently using less than its 7.5 million acre-feet (maf) apportionment, future depletion demand scenarios generally assume depletions will increase over time. In contrast, Lower Basin demands are assumed to equal full apportionment and are met through deliveries from Lake Mead, adjusted for tributary inflows and losses below the reservoir. Shortages in the Lower Basin arise primarily through prescribed delivery reductions under existing operational guidelines and agreements, including shortages and contributions established in the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead and the 2019 Drought Contingency Plan.

Long-term planning studies in the Basin have typically used narrative-based scenarios to project future demands, often assuming increasing Upper Basin demands and fixed apportionments for the Lower Division States and the United Mexican States (Mexico) (7.5 maf and 1.5 maf, respectively), with reductions implemented according to operating policies. Although useful, narrative-based scenarios embed assumptions about the timing and magnitude of future change, making it difficult to isolate the relationships between input assumptions and modeled system vulnerabilities.

The purpose of this sensitivity analysis is to evaluate how alternatives respond to different Upper Basin demand assumptions (differences in Lower Basin demands are already represented through the alternatives' shortage and surplus provisions). To more transparently examine how combinations of supply and demand affect system vulnerability, this appendix evaluates multiple Upper Basin depletion demand scenarios, including several steady-state depletion demand levels. These steady-state scenarios span a broad range of plausible future depletion demands without relying on narrative assumptions about how those depletion demands may evolve over time.

The analysis performed in this appendix is designed to inform a comparison among alternatives in this Final Environmental Impact Statement (EIS) and is not an interpretation or determination of the quantity of water legally available for use in the Upper Basin under the Law of the River and existing legal frameworks.

The Upper Basin depletion demand scenarios evaluated in this sensitivity analysis include:

- Upper Colorado River Commission's updated 2016 Depletion Demand Schedule (2016 UCRC)[1]
- 90 percent 2016 UCRC
- Steady-State 4.5 maf
- Steady-State 5.0 maf
- Steady-State 5.5 maf
- Steady-State 6.0 maf

Section I.2 describes these scenarios in more detail, and **Section I.3** presents a sensitivity analysis comparing the effects of the different depletion demand scenarios on system metrics, robustness, and vulnerability across the alternatives evaluated in this Final EIS.

I.2 Alternative Upper Basin Depletion Demand Scenarios

The 2016 UCRC depletion demand schedule, adopted by the Upper Colorado River Commission on June 14, 2022, is the depletion demand scenario used in the official version of CRSS and the depletion demand scenario used in the Final EIS modeling outside of this sensitivity analysis[2]. This depletion demand schedule is provided by the Upper Division States and the UCRC on a decadal and sector basis; the Bureau of Reclamation (Reclamation) then worked with the states to disaggregate to the spatial (sector by CRSS sub-basin) and temporal (monthly) level necessary for CRSS. The Arizona portion of the Upper Basin demand schedule was developed by Reclamation and is primarily comprised of Navajo Nation uses. The representation of the Upper Colorado Basin Tribes in the UCRC depletion demand schedule was presented in documentation dated July 13, 2022, that outlines the differences between the 2018 Tribal Water Study demand schedules and the

[1] Upper Colorado River Commission (UCRC) & Upper Division States. (2022, June 14). *Combined Resolution and Updated 2016 Depletion Demand Schedule.* Upper Colorado River Commission. Retrieved from http://www.ucrcommission.com/wp-content/uploads/2022/06/UCRC-and-Upper-Division-States-Combined-Resolution-and-Updated-2016-Depletion-Demand-Schedule-June-14-2022-1.pdf.

[2] CRSS explicitly models select reservoir evaporation, so the demand schedules used in CRSS do not include reservoir evaporation from Lake Powell, and Flaming Gorge, Blue Mesa, Morrow Point, Navajo, McPhee, Dillon, Granby, Homestake, and Willow Creek Reservoirs.

updated 2016 Depletion Demand Schedule[3,4]. See **Appendix L**, Upper Division States Depletion Schedules, for additional details.

For this sensitivity analysis, five additional Upper Basin depletion demand scenarios were developed using the 2016 UCRC depletion demand schedule as the baseline. The "90 percent 2016 UCRC" scenario was created by multiplying the 2016 UCRC depletion demand schedule by 0.9 for all months. Four additional steady-state depletion demand scenarios span a range of plausible future depletion demands from 4.5 to 6.0 maf in 0.5-maf increments. These steady-state scenarios were created by scaling the 2042 depletion demands from the 2016 UCRC depletion demand schedule so that the total Upper Basin depletion demand equals the target steady-state volume. The year 2042 was selected because it is the midpoint of a 30-year simulation period[5]. Together, these incremental steady-state depletion demand scenarios allows for a more systematic analysis of how combinations of supply and depletion demands affect system vulnerability.

Figure I-1 through **Figure I-6** show the six Upper Basin depletion demand scenarios used in this sensitivity analysis, along with the modeled Upper Basin depletions from the Continued Current Strategies (CCS) Comparative Baseline. For each depletion demand scenario, modeled Upper Basin depletions under the other alternatives would be very similar to those under CCS because all alternatives use the same assumptions for hydrology and modeled operations in reservoirs and reaches above Lake Powell. The only differences in modeled Upper Basin depletions occur when Powell Infrastructure Protection (PIP) releases are made, which differ among alternatives. PIP releases are made from Flaming Gorge, Blue Mesa, or Navajo when Lake Powell reaches low elevations (see **Appendix A**, CRSS Modeling Assumptions, for more details). These figures show how the modeled Upper Basin depletions compare to historical consumptive use and to the depletion demand schedule for a given depletion demand scenario. Because the results would not vary much by alternative, only CCS results are included.

The 2016 UCRC (**Figure I-1**) and 90 percent 2016 UCRC (**Figure I-2**) depletion demand scenarios are the only two scenarios that vary over time. The 2016 UCRC depletion demand scenario begins with a scheduled depletion demand of 5.46 maf in 2027 and increases to a maximum scheduled depletion demand of 5.99 maf in 2060. The 90 percent 2016 UCRC depletion demand schedule is 10 percent lower, with a beginning scheduled depletion demand of 4.91 maf in 2027 and increasing to a maximum scheduled depletion demand of 5.39 maf in 2060. **Appendix L,** Upper Division States Depletion Schedules, provides additional background on the development of the 2016 UCRC

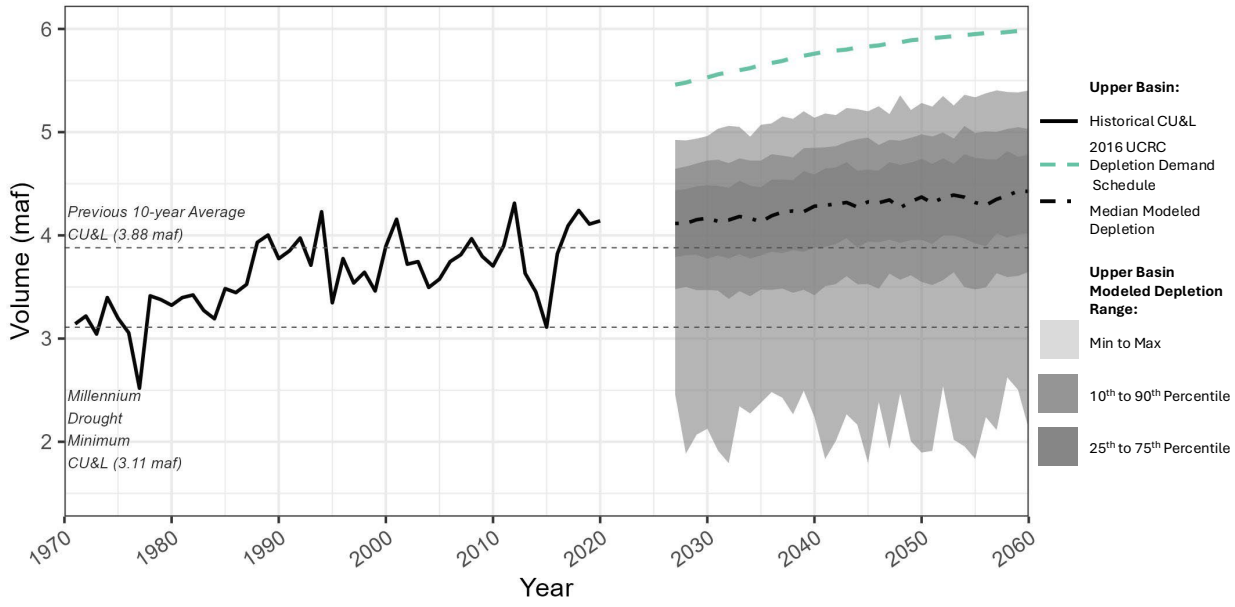
[3] The Post-2026 modeling is based on water rights of the Ute Indian Tribe of the Uintah & Ouray Reservation that have not been ratified by all parties. The Ute Indian Tribe of the Uintah & Ouray Reservation has federally reserved Indian water rights, a portion of which were federally decreed in 1923 and a portion of which have been separately recognized and put to use by the United States and the State of Utah, which are not fully resolved.

[4] The information reflected in the baseline depletion demands schedule relies on information about projected future Tribal water demands. The projections were based on information compiled in a Colorado River Basin Ten Tribes Partnership Tribal Water Study (December 2018). As discussed in Chapter 8 of that Study, the technical approach was based on the best science and information available at the time, given limitations related to timeframes and resource constraints, among other things. The Navajo Nation informed Reclamation that it was developing updated projections as part of its water development planning. Reclamation worked with the Navajo Nation as needed to update demand schedules prior to the publication of the Final EIS.

[5] This was selected before it was known if the Draft EIS would analyze 30 or 34 years and the depletion demand scenarios were not modified between the Draft and Final EIS.

schedule and its integration into CRSS. In general, these schedules represent anticipated water demands under assumed economic and hydrologic conditions, while the CRSS-simulated depletions (modeled Upper Basin depletions) represent modeled consumptive use under simulated hydrologic conditions.

Figure I-1
Annual Upper Basin Historical Consumptive Uses and Losses with 2016 UCRC Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline

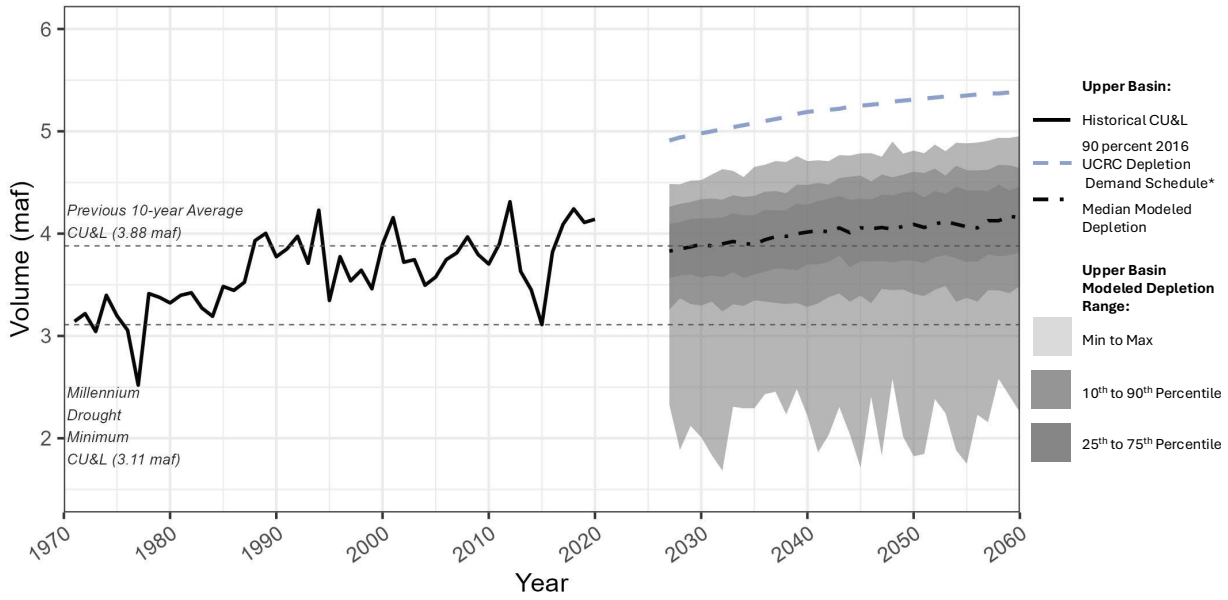


Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical consumptive uses and losses (CU&L) does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

Across all six scenarios, modeled Upper Basin depletions (shown as shaded areas in **Figure I-1** through **Figure I-6**) are lower than the input Upper Basin depletion demand schedule(shown as the colored dashed line in **Figure I-1** through **Figure I-6**), indicating that the CRSS simulations result in some level of modeled shortage in every scenario.

For the steady-state depletion demand scenarios (**Figure I-3** through **Figure I-6**), the median modeled Upper Basin depletions exhibit a slight decreasing trend over the simulation period. This trend reflects the future hydrology ensemble, which also exhibits a slight decreasing trend over time. For more information about the future hydrology used in this analysis, see **Appendix F**, Approach to Hydrologic Uncertainty. Further discussion on the Upper Basin modeled depletions is included below in **Section I.3.1**, Upper Basin Modeled Depletions.

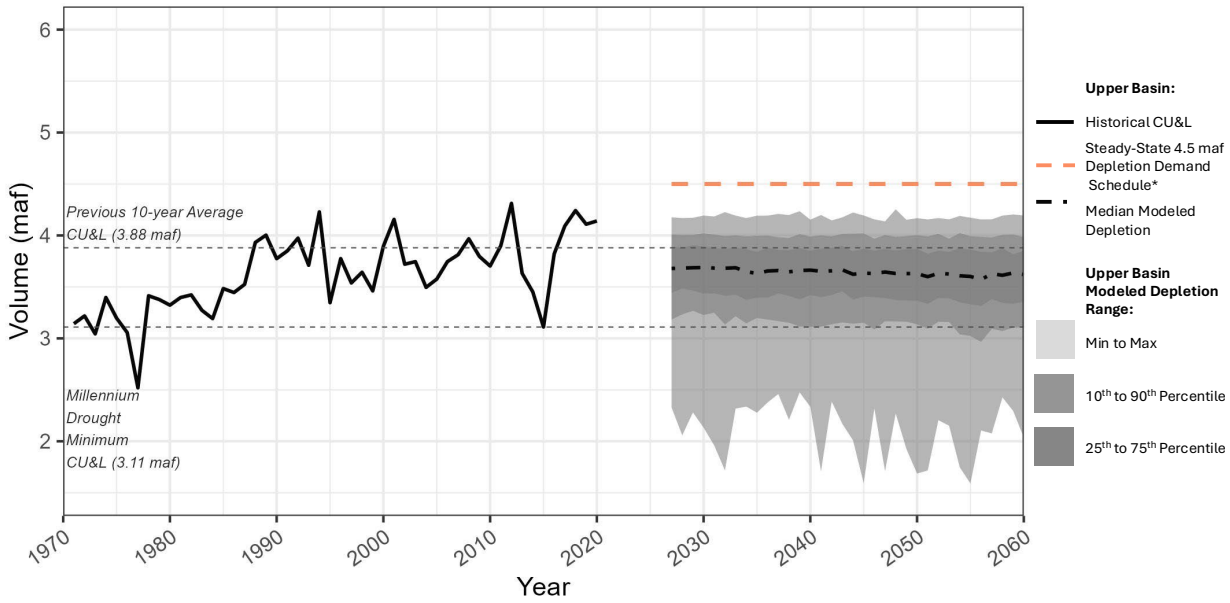
Figure I-2
Annual Upper Basin Historical Consumptive Uses and Losses with 90 percent 2016 UCRC Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline



* The 90 percent 2016 UCRC depletion demand schedule is one of six depletion demand scenarios used in the sensitivity analysis in this appendix.

Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical CU&L does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

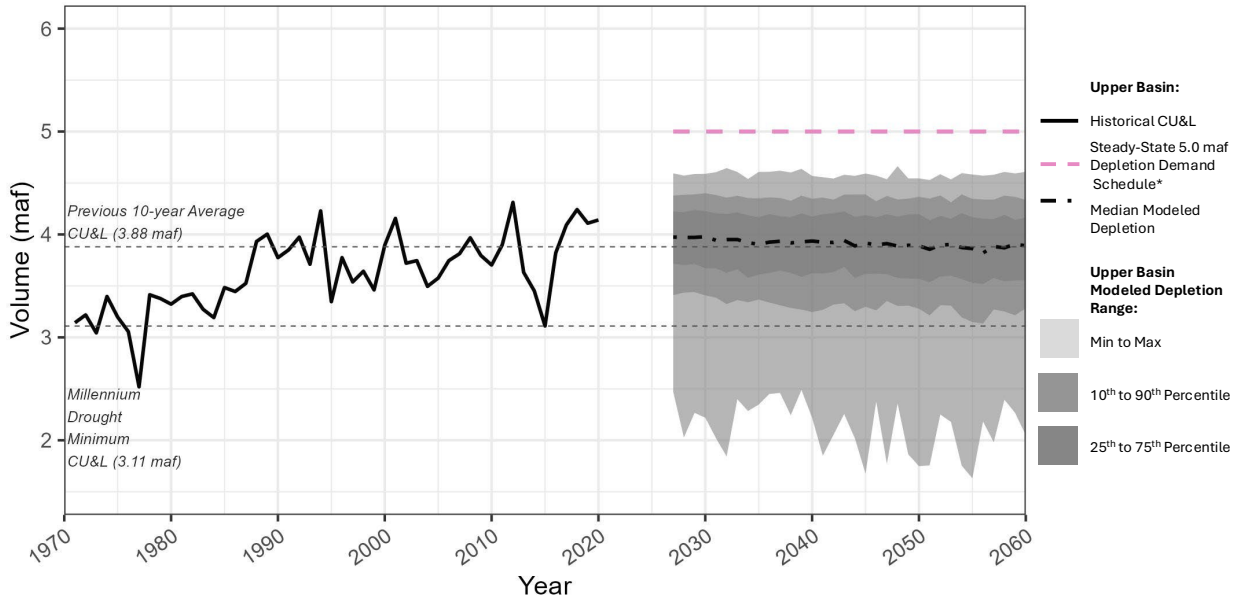
Figure I-3
Annual Upper Basin Historical Consumptive Uses and Losses with Steady-State 4.5 maf Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline



* The Steady-State 4.5 maf depletion demand schedule is one of six depletion demand scenarios used in the sensitivity analysis in this appendix.

Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical CU&L does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

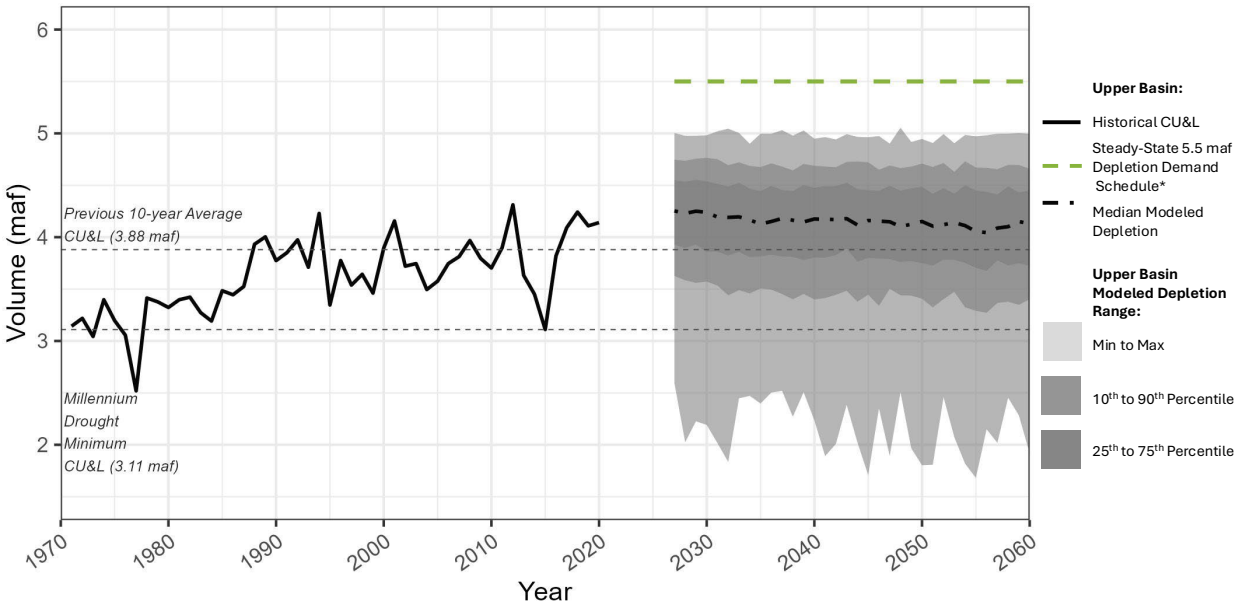
Figure I-4
Annual Upper Basin Historical Consumptive Uses and Losses with Steady-State 5.0 maf Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline



* The Steady-State 5.0 maf depletion demand schedule is one of six depletion demand scenarios used in the sensitivity analysis in this appendix.

Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical CU&L does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

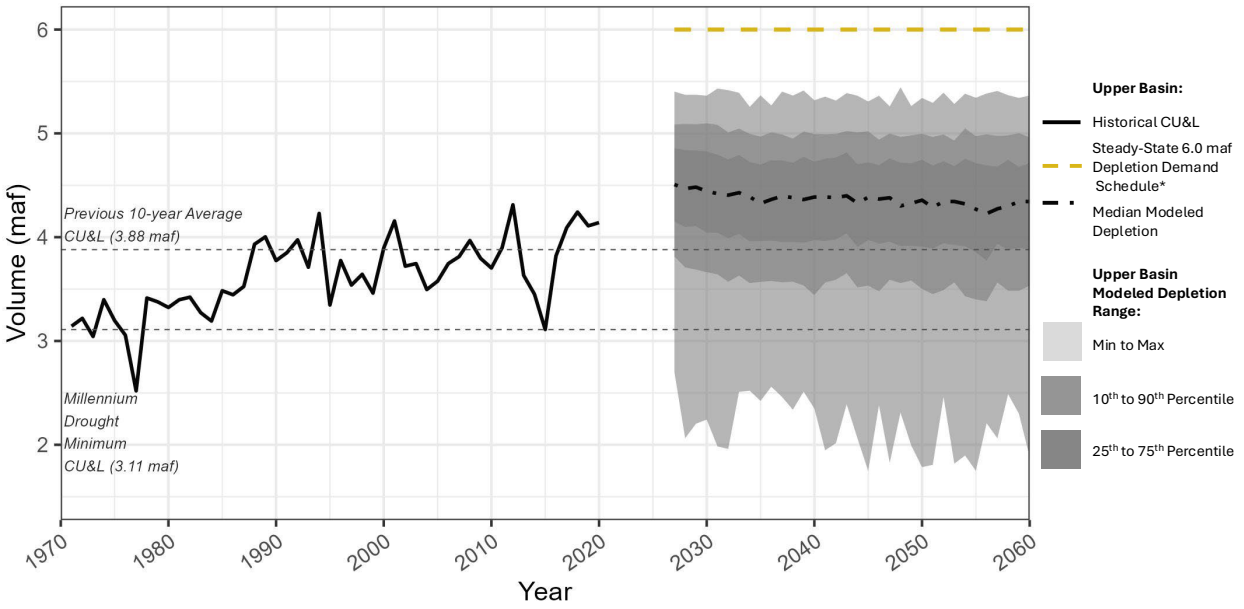
Figure I-5
Annual Upper Basin Historical Consumptive Uses and Losses with Steady-State 5.5 maf Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline



* The Steady-State 5.5 maf depletion demand schedule is one of six depletion demand scenarios used in the sensitivity analysis in this appendix.

Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical CU&L does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

Figure I-6
Annual Upper Basin Historical Consumptive Uses and Losses with Steady-State 6.0 maf Future Depletion Demand Schedule and Upper Basin Modeled Depletions, Continued Current Strategies Comparative Baseline



* The Steady-State 6.0 maf depletion demand schedule is one of six depletion demand scenarios used in the sensitivity analysis in this appendix.
Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation. To be comparable to the CRSS input and results, the historical CU&L does not include reservoir evaporation undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation but does include remaining Upper Basin reservoirs.

I.3 Sensitivity Analysis

For this sensitivity analysis, the six Upper Basin depletion demand scenarios were evaluated in combination with the seven different reservoir operating policies analyzed in this Final EIS:

- No Action Alternative
- Basic Coordination Alternative
- Enhanced Coordination Alternative
- Maximum Operational Flexibility Alternative
- Supply Driven Alternative (Lower Basin [LB Priority] approach)
- Representative Preferred Alternative
- Continued Current Strategies (CCS) Comparative Baseline

Only the Supply Driven Alternative using the LB Priority shortage distribution approach is used for this sensitivity analysis, as the emphasis is not on how different Lower Division State shortage distributions affect the results.

Each model was run with the same hydrologic ensemble and the initial reservoir conditions used throughout the Final EIS. See **Appendix A**, CRSS Modeling Documentation, for modeling assumptions associated with each alternative, and **Appendix F**, Approach to Hydrologic Uncertainty, and **Appendix G**, Initial Reservoir Conditions, for additional details on hydrology and initial condition assumptions.

The analyses presented in this appendix are based on the Decision Making Under Deep Uncertainty (DMDU) framework used in this Final EIS. DMDU is a non-probabilistic evaluation framework that compares scenarios across a broad range of plausible future conditions and evaluates their performance under varying hydrologic conditions. Additional background and technical information on the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach, and **Chapter 3**, **Section 3.2.6** includes additional details on interpreting the figures and analyses.

The results were analyzed using the following metrics to better understand the impact of the six depletion demand scenarios on "system conditions" under each alternative:

- Upper Basin modeled depletions and modeled shortages
- Lake Powell and Lake Mead pool elevations
- Lee Ferry Compact Point 10-year volume
- Total Lower Basin reductions (shortage plus Lake Mead dead pool-related reductions)

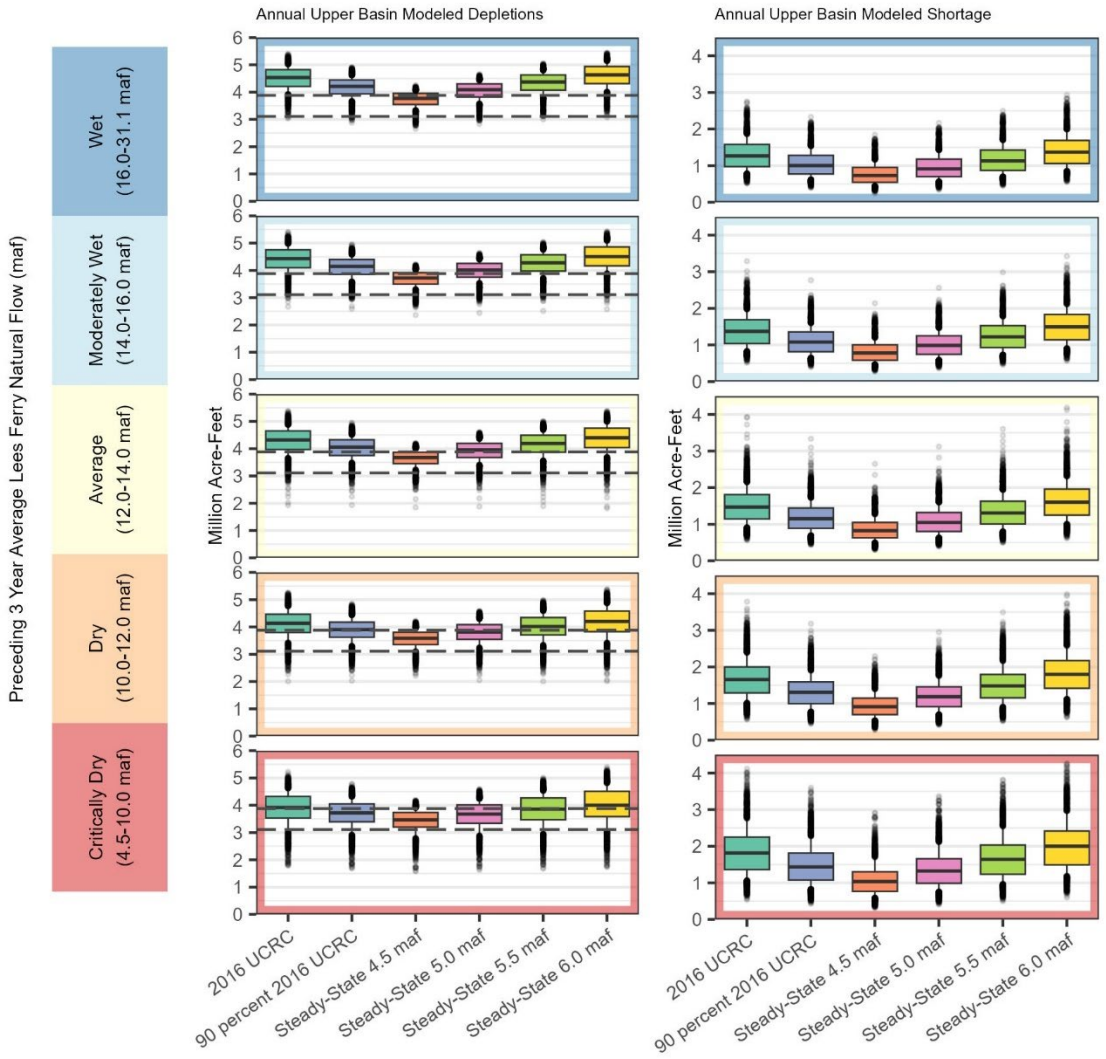
The analysis is organized into four sections. **Section I.3.1** presents Upper Basin modeled depletions and modeled shortages using conditional boxplots. **Section I.3.2** presents Lake Powell and Lake Mead pool elevations, Lee Ferry Compact Point 10-year volume, and total Lower Basin reductions using conditional boxplots. **Sections I.3.3** and **I.3.4** present robustness and vulnerability analyses, respectively, for selected Lake Powell and Lake Mead elevation thresholds.

I.3.1 Upper Basin Modeled Depletions and Modeled Shortages

Figure I-7 shows annual Upper Basin modeled depletions and modeled shortages for the CCS Comparative Baseline across all depletion demand scenarios organized by the preceding three-year average Lees Ferry natural flow. Upper Basin modeled depletions and modeled shortages are only shown for the CCS Comparative Baseline as they do not vary significantly between alternatives, as discussed in **Section I.2**. The bold center line of each box represents the median value. The top and bottom of each box captures the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and the outliers are shown as dots beyond these lines.

Dashed lines on the graph represent the previous 10-year average (3.88 maf) and the millennium drought minimum (3.11 maf) annual Upper Basin consumptive uses and losses, excluding reservoir evaporation for reservoirs with evaporation modeled explicitly in CRSS[2].

Figure I-7
Projected Annual Upper Basin Modeled Depletions and Shortage Across the 2016 UCRC Depletion Demand Schedule and Five Alternate Upper Basin Depletion Demand Scenarios Simulated Using Continued Current Strategies Comparative Baseline



Note: Future depletion demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation[2]. CRSS simulates consumptive use based on the provided depletion demand scenarios, and the available supply in each year of each simulation.

In the Dry Flow Category, the median Upper Basin modeled depletion exceeds the 3.88 maf threshold for all depletion demand scenarios except the Steady State 4.5 maf and Steady State 5.0 maf scenarios. For the Steady State 4.5 maf depletion demand scenario, the 75th percentile is within 77.0 thousand acre-feet (kaf) of the average consumptive use over the last 10 years, while the median is 294.0 kaf less than the historical average consumptive use. For the Steady State 5.0 maf depletion demand scenario, the median is 68.0 kaf less than the historical average consumptive use.

The interquartile range of the Upper Basin modeled depletions increases as the average annual depletion demand increases. In the Dry and Critically Dry Flow Categories, the interquartile ranges differ less between the depletion demand scenarios. In drier conditions, limited water availability constrains depletions, so higher depletion demands do not result in proportionally higher depletions. Across all flow categories, the interquartile ranges remain above the minimum annual Upper Basin consumptive uses and losses (excluding reservoir evaporation) from the millennium drought. The Steady State 4.5 maf depletion demand scenario is the only depletion demand scenario with a 75th percentile below the historical average consumptive use of 3.88 maf; this occurs in the Average, Dry and Critically Dry Flow Categories.

Upper Basin modeled shortages were calculated as the difference between the annual Upper Basin depletion demand scenario and the annual Upper Basin modeled depletions. The annual Upper Basin modeled shortages range between 246.0 kaf and 4.25 maf across all depletion demand scenarios, showing that modeled shortages occurred in every year of the model simulation under all analyzed hydrology sequences. Median Upper Basin modeled shortages typically range between 1.0 maf and 2.0 maf. Only the Steady State 6.0 maf depletion demand scenario reaches 2.0 maf of modeled shortage in the Critically Dry Flow Category. Both the magnitude and the interquartile range of Upper Basin modeled shortages increase under drier hydrologic conditions because a smaller portion of the depletion demand can be met. Similarly, Upper Basin modeled shortages increase as depletion demand schedules increase.

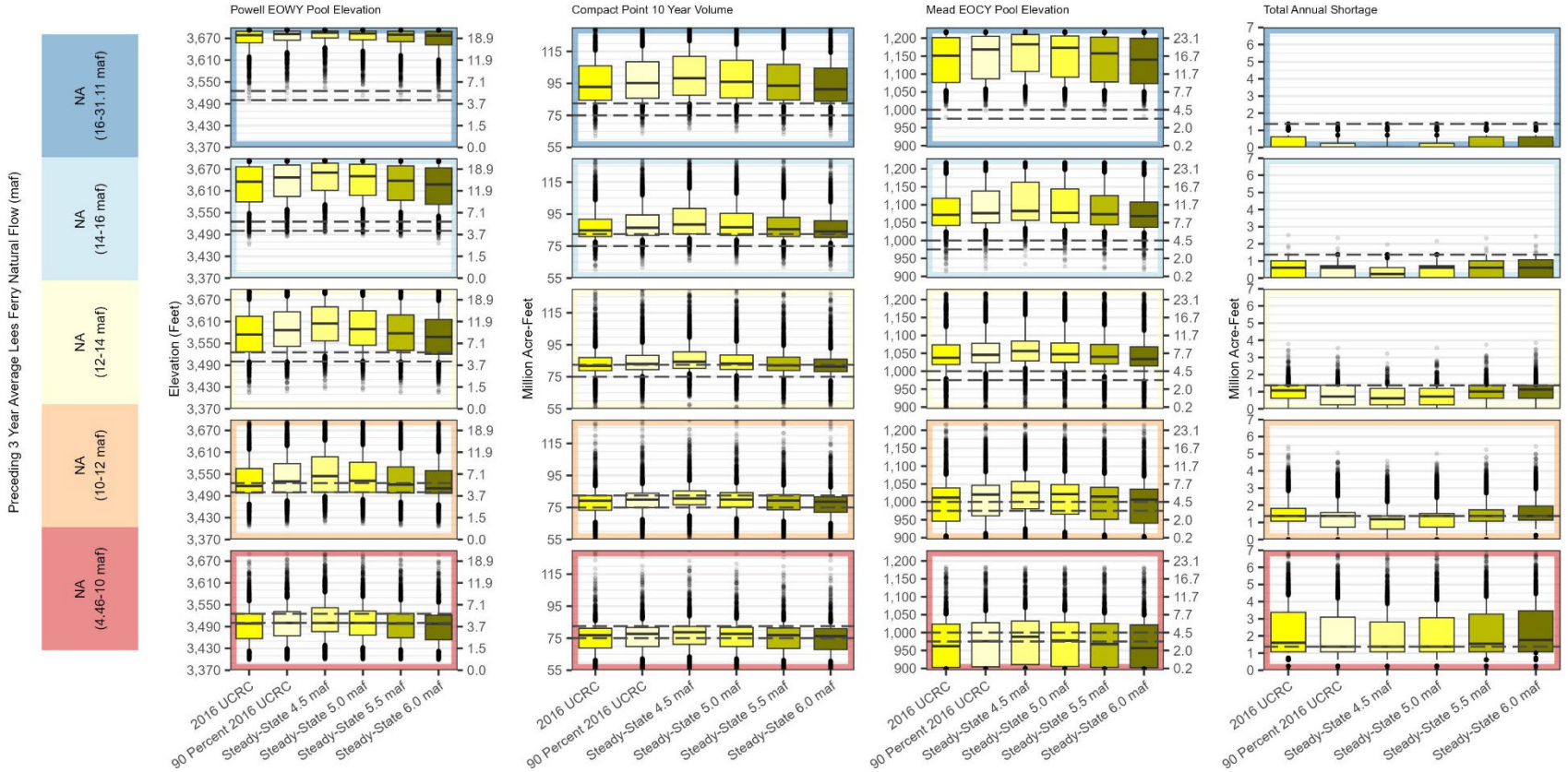
I.3.2 Impact on System Conditions

Figure I-8 through **Figure I-14** show Lake Powell end-of-water-year (EOWY) pool elevations, Lee Ferry Compact Point 10-year volumes, Lake Mead end-of-calendar-year (EOCY) pool elevations, and total Lower Basin shortage by flow category across all depletion demand scenarios for the CCS Comparative Baseline and all alternatives.

Dashed lines are included on the boxplots to identify critical elevations and thresholds. At Lake Powell, elevations 3,525 feet and 3,500 feet are included because of their importance to protecting infrastructure, power generation, and the ability to make downstream deliveries. At Lake Mead, elevations 1,000 feet and 975 feet are highlighted for the same reasons. The flow volumes of 82.5 maf and 75.0 maf are included in the Lee Ferry Compact Point 10-year volume. Finally, the Lower Basin total annual shortage (Lower Basin shortage plus dead pool-related reductions) for each alternative includes a dashed line to indicate the maximum shortage for the alternative. Total annual shortage may exceed this value because it includes dead pool-related reductions.

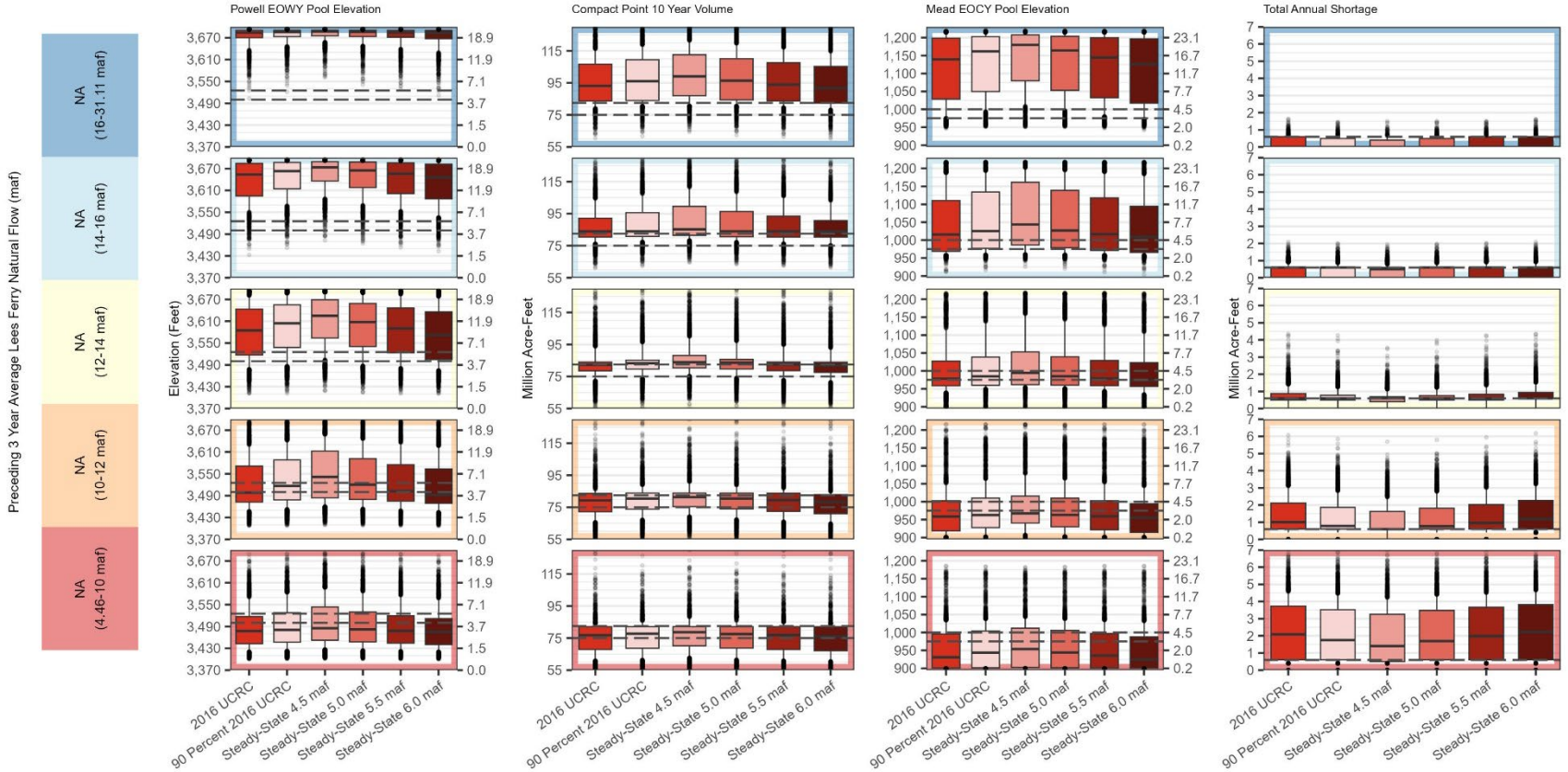
Except for the Supply Driven Alternative (LB Priority Approach), all alternatives and the CCS Comparative Baseline exhibit the same general trend. Compared with higher depletion demand scenarios, lower depletion demand scenarios result in higher Lake Powell elevations, higher Lee Ferry Compact Point 10-year volumes, higher Lake Mead elevations, and lower total Lower Basin shortages. Because higher depletion demand scenarios result in greater modeled Upper Basin depletions (see **Figure I-7**), less water flows into Lake Powell, reducing the volume of water available for release to Lake Mead.

Figure I-8
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for Continued Current Strategies Across the Six Depletion Demand Scenarios



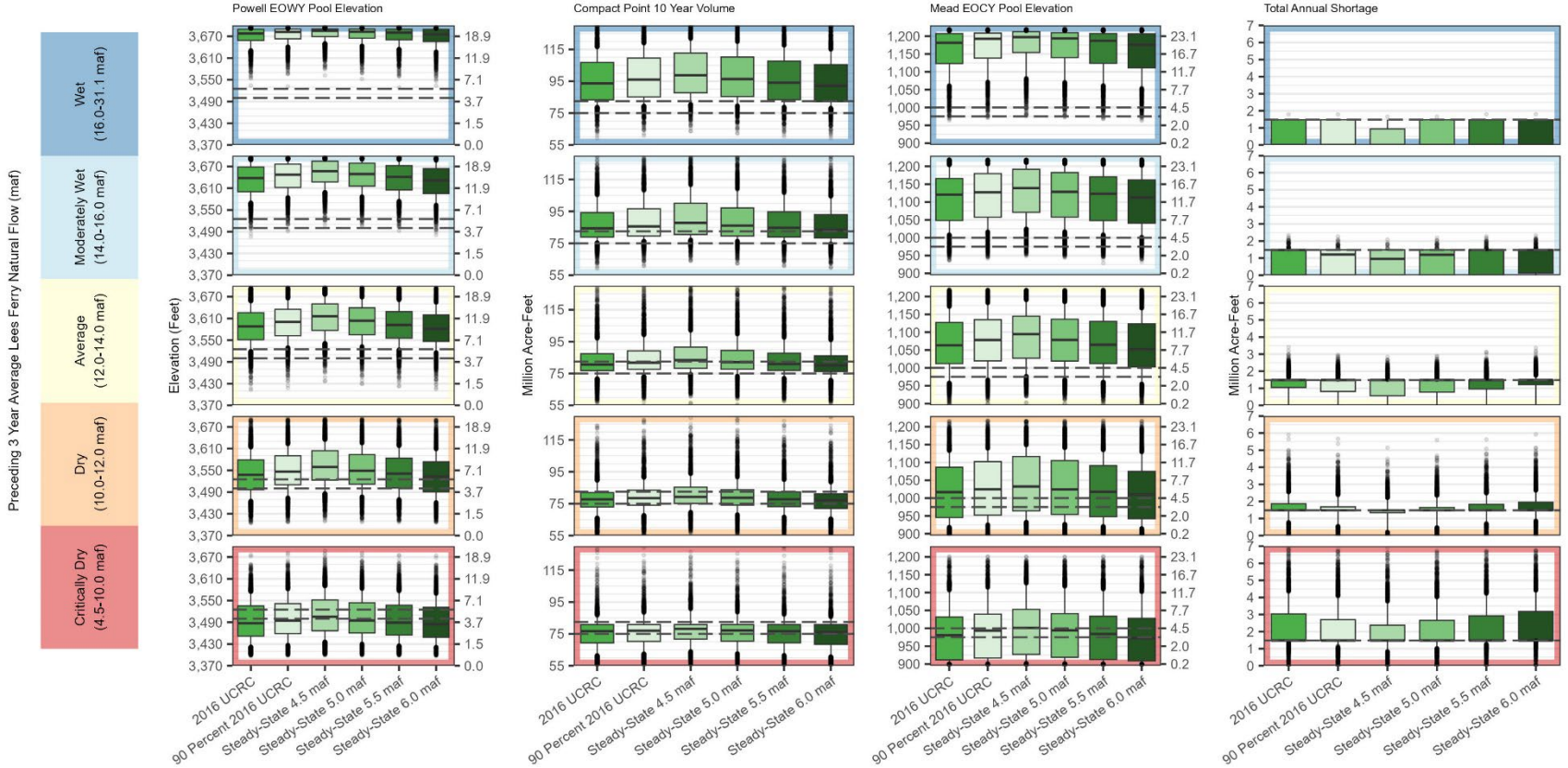
Note: The dashed line in the Total Annual Shortage column indicates a maximum reduction of 1.375 maf in the CCS Comparative Baseline.

Figure I-9
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the No Action Alternative Across the Six Depletion Demand Scenarios



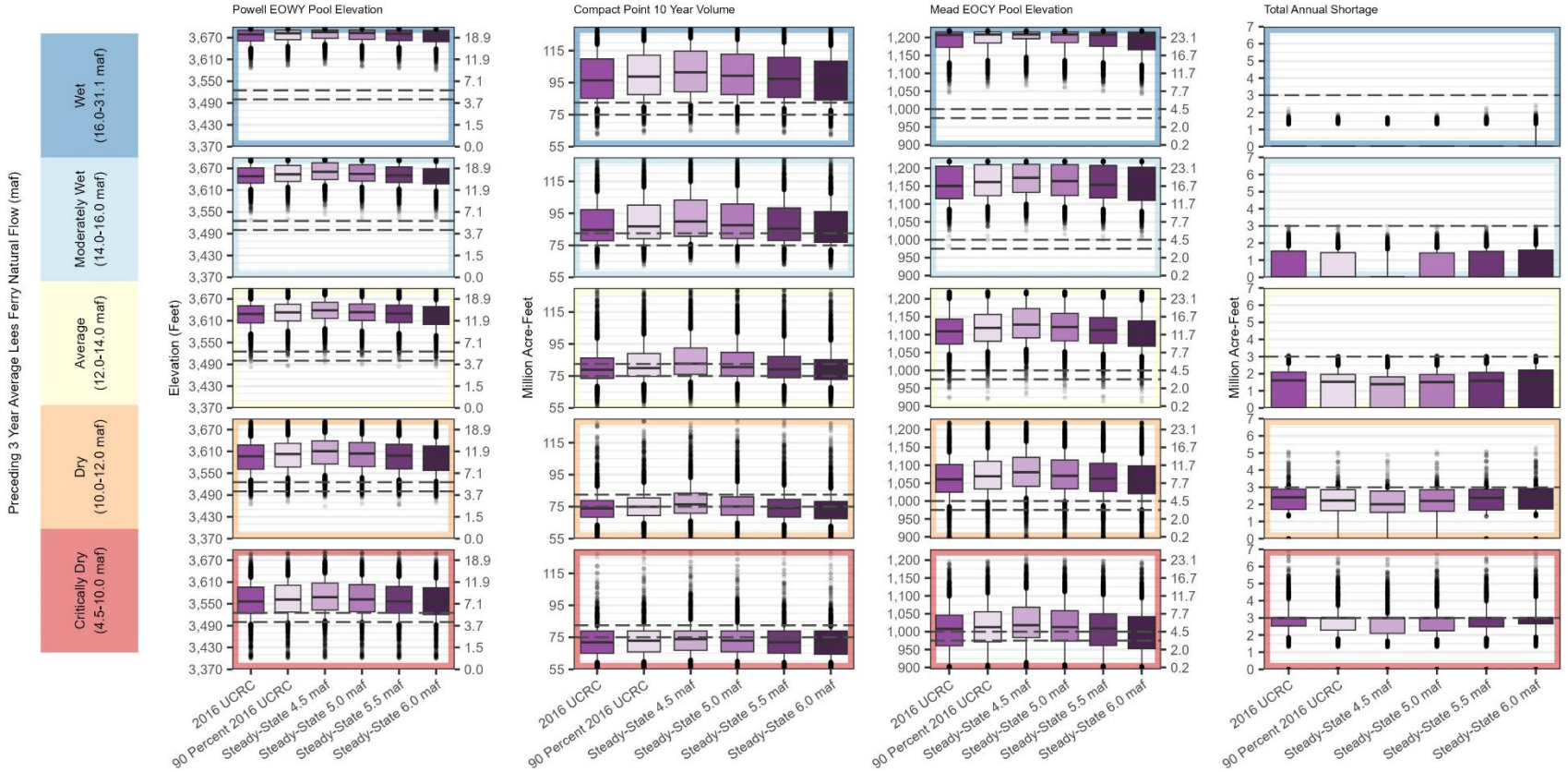
Note: The dashed line in the Total Annual Shortage column indicates a maximum shortage of 0.6 maf in the No Action Alternative.

Figure I-10
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the Basic Coordination Alternative across the Six Depletion Demand Scenarios



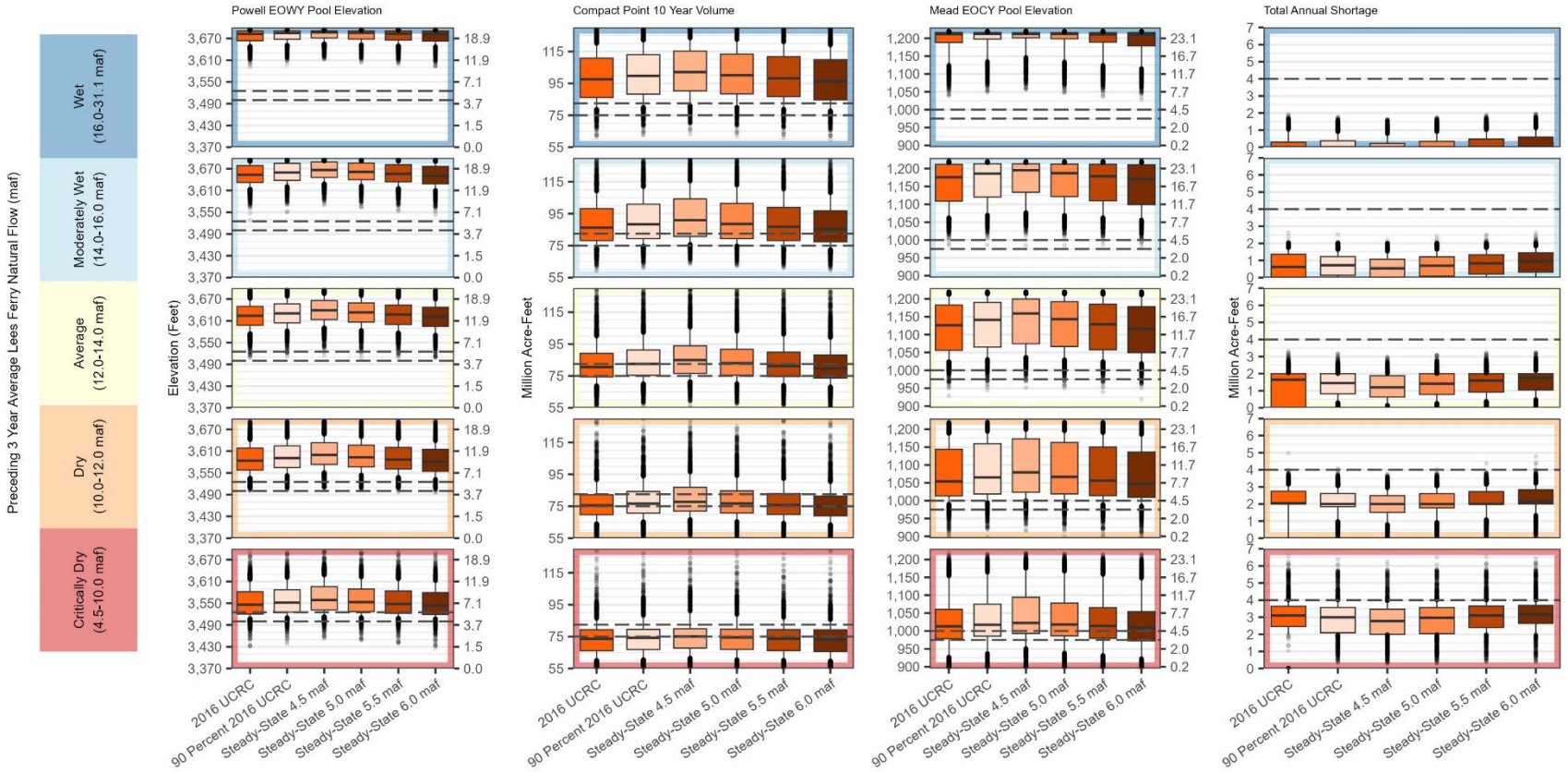
Note: The dashed line in the Total Annual Shortage column indicates a maximum shortage of 1.48 maf in the Basic Coordination Alternative.

Figure I-11
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the Enhanced Coordination Alternative Across the Six Depletion Demand Scenarios



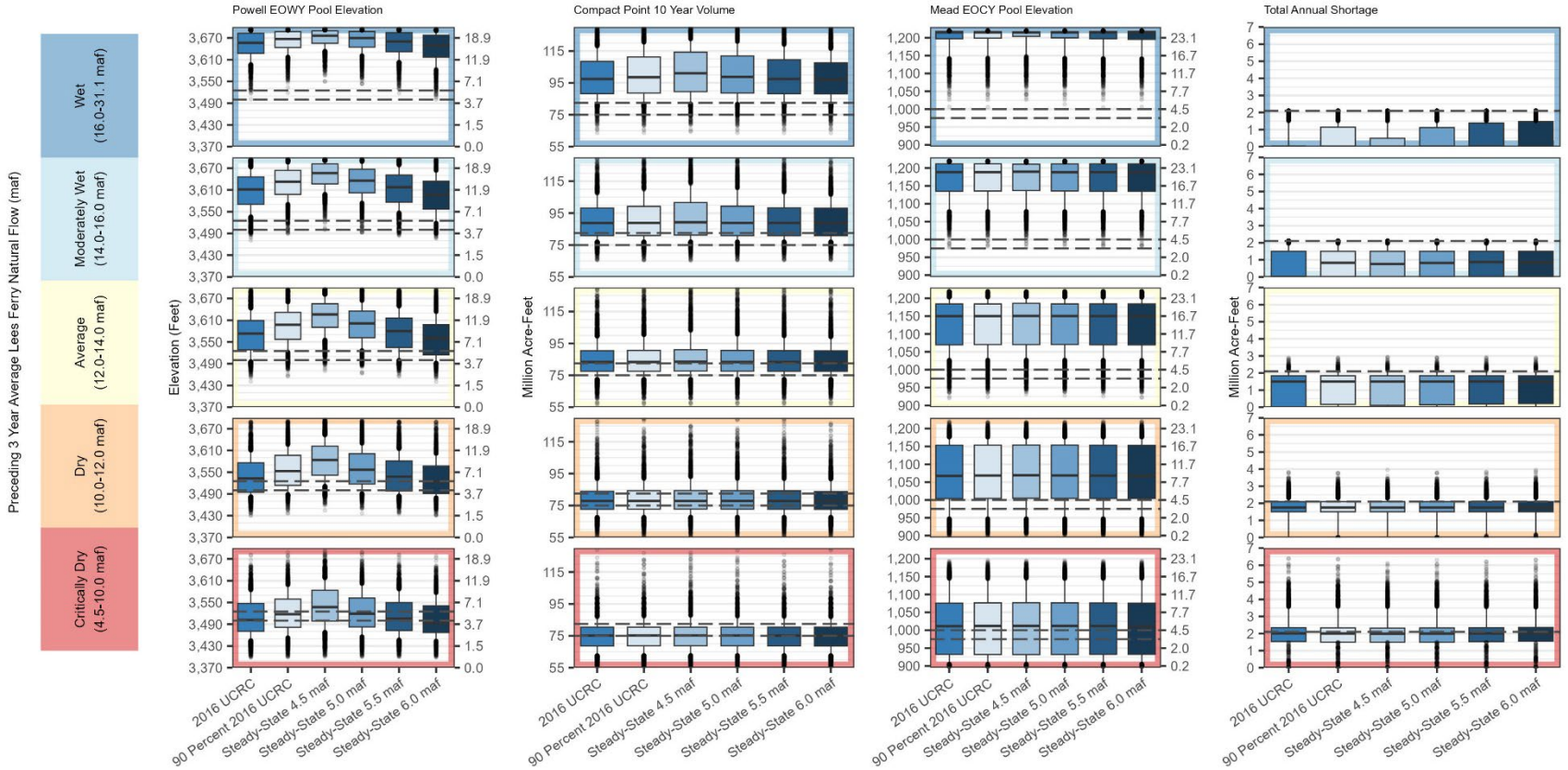
Note: The dashed line in the Total Annual Shortage column indicates a maximum shortage of 3.0 maf in the Enhanced Coordination Alternative.

Figure I-12
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the Maximum Operational Flexibility Alternative Across the Six Depletion Demand Scenarios



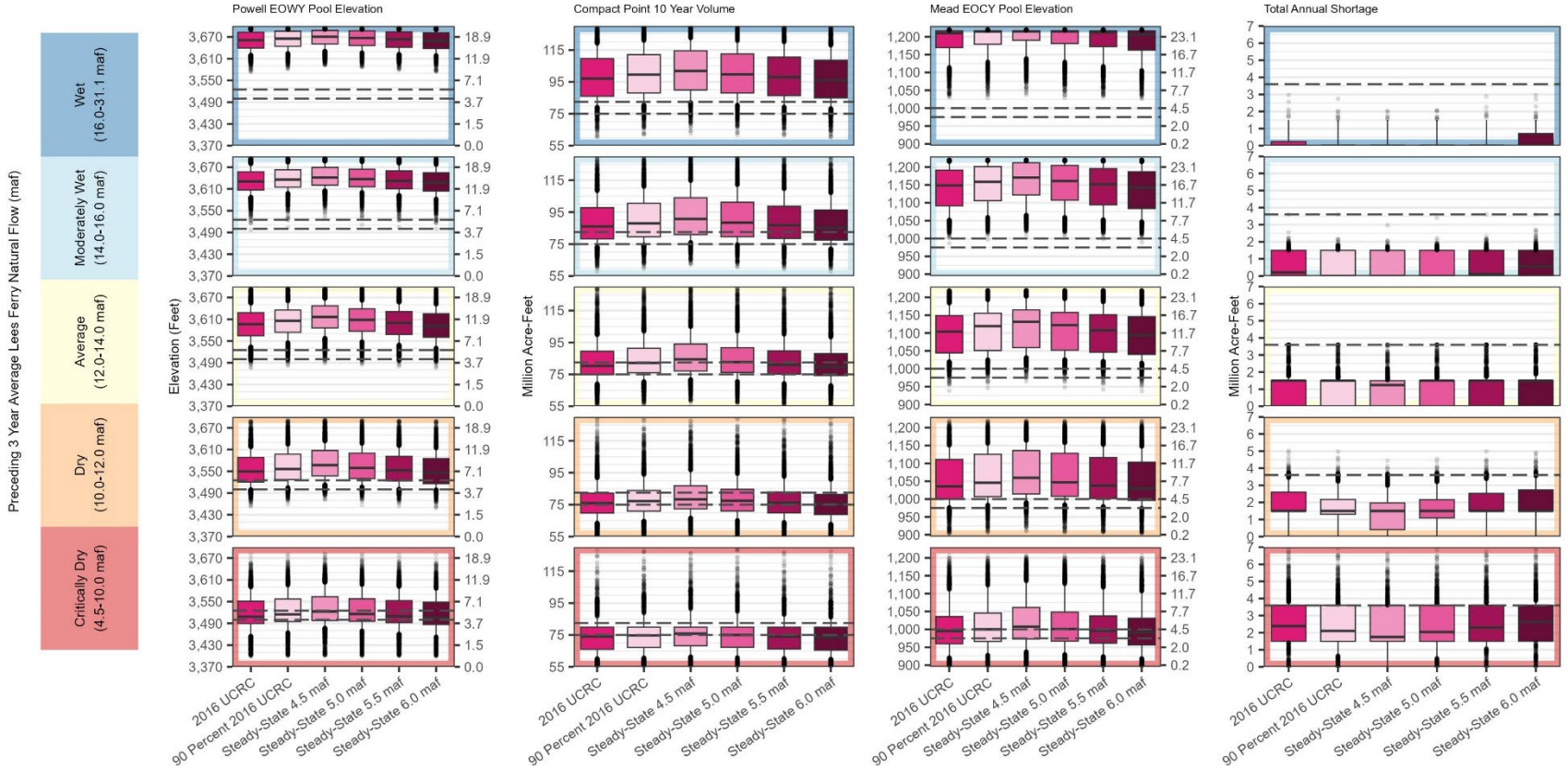
Note: The dashed line in the Total Annual Shortage column indicates a maximum shortage of 4.0 maf in the Maximum Operational Flexibility Alternative.

Figure I-13
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the Supply Driven Alternative (LB Priority Approach) Across the Six Demand Scenarios



Note: The dashed line in the Total Annual Shortage column indicates a maximum shortage of 2.1 maf in the Supply Driven Alternative (LB Priority Approach).

Figure I-14
Lake Powell EOWY Elevation, Lee Ferry Compact Point 10-Year Volumes, Lake Mead EOCY Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead Pool-Related Reductions) for the Representative Preferred Alternative Across the Six Demand Scenarios



Note The dashed line in the Total Annual Shortage column indicates a maximum shortage of 3.6 maf in the Representative Preferred Alternative.

For the Supply Driven Alternative (LB Priority approach) (**Figure I-13**), lower steady-state depletion demand scenarios also result in higher Lake Powell elevations. Because Lake Powell releases are based on 65 percent of the preceding 3-year average Lees Ferry natural flow, there are few differences in Lake Mead elevations among the depletion demand scenarios. Under this alternative, Lake Powell releases are determined irrespective of Lake Powell elevation, resulting in similar downstream conditions regardless of the depletion demand scenario. Similarly, there are also few differences in total Lower Basin shortage across the depletion demand scenarios because shortages are based on Lake Mead elevation. Differences in the Compact Point 10-year volumes are observed across depletion demand scenarios, primarily due to infrastructure constraints at high and low Lake Powell elevations. At higher Lake Powell elevations, which occur more frequently in the Moderately Wet and Wet Flow Categories, lower steady-state depletion demand scenarios result in more instances of spill avoidance releases, which increases the Compact Point 10-year volumes.

I.3.3 Robustness

A robustness analysis was used to evaluate each alternative's ability to maintain Lake Powell and Lake Mead above critical elevation thresholds. In this context, robustness is defined as an alternative's ability to achieve a specified level of performance across a broad range of potential future conditions under a given depletion demand scenario.

For this analysis, the specified levels of performance are maintaining Lake Powell above elevation 3,500 feet[6] and Lake Mead above elevation 975 feet[7] during every month of the 34-year simulation period. A modeled future that meets these performance criteria is considered a "successful future." Robustness is expressed as the percentage of the 400 modeled futures that are successful for each alternative–depletion demand scenario combination.

Table I-1 and **Table I-2** compare the robustness of each alternative and depletion demand scenario with respect to maintaining reservoir elevations above 3,500 feet at Lake Powell and 975 feet at Lake Mead, respectively. Of note, the Representative Preferred Alternative results presented in this appendix do not include PIP releases, which would provide additional protection against reaching critical thresholds. In **TA 3**, Hydrologic Resources, **Figures TA 3-7** and **TA 3-12** present the robustness of Lake Powell at elevation 3,500 feet and Lake Mead at elevation 975 feet, respectively, with PIP releases included.

[6] This elevation at Lake Powell provides a 10-foot buffer to protect critical infrastructure, water delivery, and hydropower, which are critically impacted at an elevation of 3,490 feet. See **Section TA 3.2.1**, Issue 1, in **TA 3,** Hydrologic Resources.
[7] This elevation at Lake Mead provides 25-foot buffer from 950 feet - the elevation below which water can only be released through the intake towers, constraining both the volume of water able to be released as well as the ability to generate power.

Table I-1
Robustness of Lake Powell Elevation 3,500 Feet

	Continued Current	No Action	Basic Coordination	Enhanced Coordination	Max Flexibility	Supply Driven (LB Priority)	Representative Preferred
2016 UCRC	18%	4%	13%	74%	86%	18%	28%
90% 2016 UCRC	23%	4%	14%	77%	91%	28%	34%
Steady-State 4.5 maf	25%	4%	16%	79%	94%	45%	40%
Steady-State 5.0 maf	23%	4%	14%	76%	91%	30%	35%
Steady-State 5.5 maf	19%	3%	13%	73%	89%	21%	31%
Steady-State 6.0 maf	17%	3%	11%	70%	86%	15%	26%

Note: Percent of futures in which Lake Powell remains above 3,500 feet in 100 percent of months.

Table I-1 shows that, across all alternatives, the Steady State 4.5 maf scenario resulted in the highest robustness, while the Steady State 6.0 maf scenario resulted in the lowest robustness for maintaining Lake Powell above 3,500 feet. For most alternatives, the different depletion demand scenarios resulted in similar levels of robustness, with differences typically ranging from 1 to 14 percent. The Supply Driven Alternative (LB Priority approach) is the clear outlier. Its robustness varies by 30 percent, ranging from 45 percent of futures for the Steady State 4.5 maf scenario to 15 percent of futures for the Steady State 6.0 maf scenario. Because Lake Powell releases are based on 65 percent of the preceding 3-year average natural flow rather than reservoir elevation, the required release in Supply Driven Alternative (LB Priority approach) is the same regardless of the Lake Powell elevation. As a result, there is a large difference in robustness at Lake Powell across the assumed depletion demand scenarios. The Representative Preferred Alternative exhibits the next largest difference in robustness between the Steady State 4.5 maf and Steady State 6.0 maf scenarios, at 14 percent.

Table I-2 compares the robustness of alternatives with respect to Lake Mead's monthly pool elevation remaining above elevation 975 feet in all months.

Table I-2
Robustness of Lake Mead Elevation 975 Feet

	Continued Current	No Action	Basic Coordination	Enhanced Coordination	Max Flexibility	Supply Driven (LB Priority)	Representative Preferred
2016 UCRC	38%	21%	50%	65%	70%	61%	50%
90% 2016 UCRC	43%	24%	55%	69%	75%	61%	54%
Steady-State 4.5 maf	48%	25%	58%	72%	79%	61%	61%
Steady-State 5.0 maf	43%	24%	55%	68%	75%	61%	54%
Steady-State 5.5 maf	39%	22%	51%	65%	70%	61%	52%
Steady-State 6.0 maf	35%	18%	46%	61%	68%	60%	49%

Note: Percent of futures in which Lake Mead remains above 975 feet in 100 percent of months.

As at Lake Powell, the Steady State 4.5 maf scenario resulted in the highest robustness, while the Steady State 6.0 maf scenario resulted in the lowest robustness for maintaining Lake Mead above elevation 975 feet. Also consistent with the Lake Powell results, all alternatives except the Supply Driven Alternative (LB Priority approach) exhibited similar levels of robustness across the depletion demand scenarios, with differences typically ranging from 7 to 13 percent. In contrast to Lake Powell results, the Supply Driven Alternative (LB Priority approach) showed no change in robustness at Lake Mead across the depletion demand scenarios. This is because Lake Powell releases are computed as 65 percent of the preceding 3-year average natural flow, producing the same release for a given hydrologic year regardless of the assumed Upper Basin depletion demand scenario.

I.3.4 Vulnerability

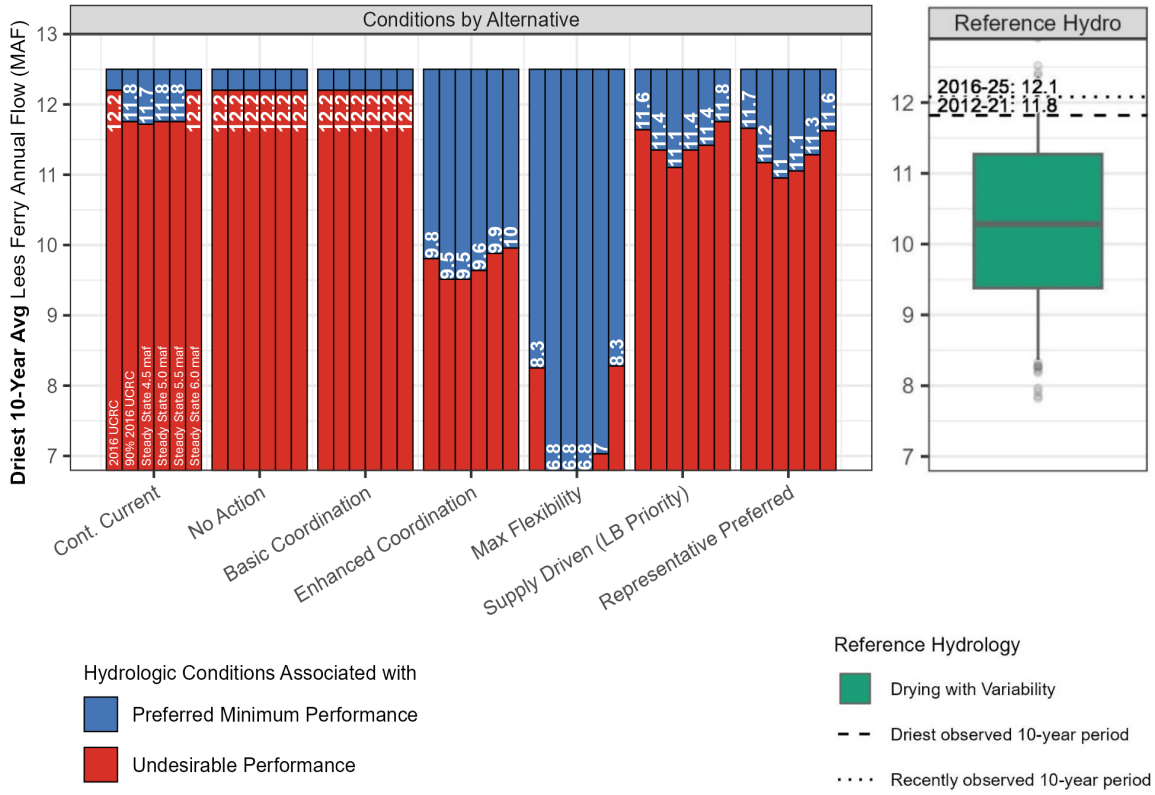
A vulnerability analysis was used to identify the hydrologic conditions that tend to result in an undesirable outcome. In this context, vulnerability was defined as an alternative's susceptibility to undesirable performance under a given depletion demand scenario across a broad range of potential future hydrologic conditions.

For this analysis, undesirable performance is defined as Lake Powell falling below elevation 3,500 feet or Lake Mead falling below elevation 975 feet at any time during the 34-year simulation period. Vulnerability complements the robustness analysis by using information from both successful and unsuccessful modeled futures to identify a skillful hydrologic predictor that relates hydrologic conditions to the likelihood a modeled outcome will be successful or unsuccessful under a given alternative and depletion demand scenario. This analysis is useful because it characterizes each alternative-depletion demand scenario combination in terms of the hydrologic conditions that are likely to result in undesirable performance, thereby identifying the conditions under which an alternative is vulnerable.

Figure I-15 shows the flow conditions likely to cause Lake Powell elevations to fall below 3,500 feet for each alternative and depletion demand scenario. This definition of undesirable performance is based on the robustness analysis presented in **Table I-1** above, which defined a future as successful when an alternative maintains elevations above 3,500 feet in every month.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was identified as the streamflow summary statistic most skillful at predicting undesirable performance (see **Appendix E**, DMDU Overview and Approach, **Section E.3** for further information). Vulnerability thresholds for each alternative-depletion demand scenario combination are compared to the observed record and the Drying with Variability Ensemble (shown in the Reference Hydrology panel) using this streamflow summary statistic. For reference, the driest observed 10-year average flow (2012-2021; 11.8 maf) and the most recent 10-year average flow (2016-2025; 12.1 maf) are also shown as dashed and dotted lines, respectively.

Figure I-15
Conditions that Could Cause Lake Powell Elevation to Fall below 3,500 feet in One or More Months Across All Depletion Demand Scenarios and Alternatives



Across all alternatives, the Steady State 4.5 maf scenario generally has the lowest vulnerability threshold, indicating that the alternatives are less vulnerable under this depletion demand scenario than under the higher depletion demand scenarios. Vulnerability under the 2016 UCRC scenario follows closely behind that of the Steady State 6.0 maf scenario.

The range of vulnerability thresholds across depletion demand scenarios indicates how sensitive each alternative is to the assumed depletion demands. The No Action and Basic Coordination Alternatives show negligible sensitivity, with identical vulnerability thresholds across all depletion demand scenarios. This is consistent with the robustness scores in **Table I-1**, which indicate these alternatives perform poorly regardless of depletion demand scenario.

The CCS Comparative Baseline and Enhanced Coordination Alternative have vulnerability thresholds that vary by 0.5 maf across depletion demand scenarios, while the Supply Driven Alternative (LB Priority approach) and the Representative Preferred Alternative have vulnerability thresholds that vary by 0.7 maf. These small ranges indicate relatively low sensitivity to the depletion demand scenario. For the Maximum Operational Flexibility Alternative, the vulnerability threshold is at or near the bottom of the figure (ranging from 6.8 to 7.0 maf) for the 90 percent 2016 UCRC, Steady State 4.5, 5.0, and 5.5 maf scenarios. Under the 2016 UCRC and Steady State 6.0 maf scenarios, the thresholds are noticeably higher at 8.3 maf. However, this is likely due to the high

robustness scores obtained by the Maximum Operational Flexibility Alternative, which can make it difficult to identify and compare vulnerability thresholds across depletion demand scenarios. In this case, robustness scores are a better indicator of sensitivity, which only vary between 86 percent under the Steady State 6.0 maf scenario to 94 percent under the Steady State 4.5 maf scenario.

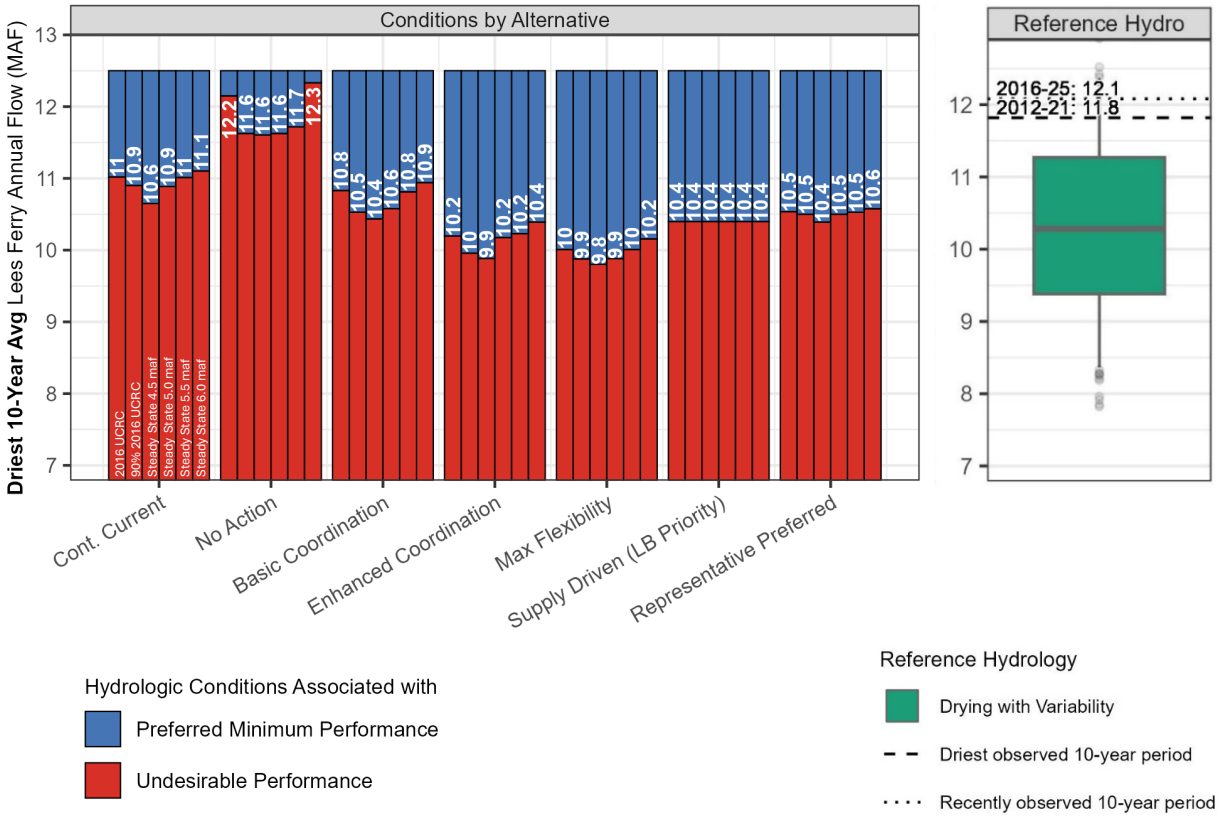
Comparing the vulnerability thresholds with the reference hydrology panel indicates that all alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives would be reasonably likely to experience Lake Powell elevations below 3,500 feet over the next 34 years, regardless of the depletion demand scenario. This is because the alternatives are vulnerable to about 75 percent or more of the traces in the Drying with Variability Ensemble, which represents a drier future with conditions like those experienced in recent history. The Enhanced Coordination Alternative may or may not be vulnerable, since it is vulnerable under nearly 50 percent of the traces in the Drying with Variability Ensemble but not vulnerable based on conditions that have occurred historically, regardless of the depletion demand scenarios. The Maximum Operational Flexibility Alternative is reasonably unlikely to experience elevations below 3,500 feet because it is vulnerable under less than 10 percent of the traces in the Drying with Variability Ensemble and not vulnerable under historical conditions, regardless of the depletion demand scenarios.

Figure I-16 shows the flow conditions likely to cause Lake Mead to fall below 975 feet for each alternative-depletion demand scenario combination. This definition of undesirable performance is based on the robustness analysis presented in **Table I-2** above, which defined a future as successful when an alternative maintains elevations above 975 feet in every month.

Like the Lake Powell vulnerability analysis, this vulnerability analysis identified the driest 10-year average Lees Ferry annual flow as the streamflow summary statistic most skillful at predicting undesirable performance.

Similar to the Lake Powell vulnerability analysis, the Steady State 4.5 maf scenario generally has the lowest vulnerability thresholds across depletion demand scenarios, while the Steady State 6.0 maf scenario generally has the highest vulnerability thresholds. The Supply Driven Alternative (LB Priority approach) is not sensitive to the depletion demand scenario, with the same vulnerability threshold across all depletion demand scenarios. The Representative Preferred Alternative is relatively insensitive, with vulnerability thresholds varying by only 0.2 maf. The remaining action alternatives and the CCS Comparative Baseline are also relatively insensitive, with thresholds varying by 0.4 maf for the Maximum Operational Flexibility Alternative and 0.5 maf for both the CCS Comparative Baseline and Enhanced Coordination Alternative. The No Action Alternative is the most sensitive, with vulnerability thresholds varying by 0.7 maf.

Figure I-16
Conditions that Could Cause Lake Mead Elevation to Fall B 975 feet in One or More Months Across All Depletion Demand Scenarios and Alternatives



Comparing the vulnerability thresholds with the Drying with Variability Ensemble indicates that the CCS Comparative Baseline, No Action Alternative, and Basic Coordination Alternative would be reasonably likely to experience elevations below 975 feet over the next 34 years, regardless of the depletion demand scenario. The No Action Alternative is vulnerable under conditions similar to those observed in recent history and in over 75 percent of traces in the Drying with Variability Ensemble. Although the CCS Comparative Baseline and Basic Coordination Alternative are not vulnerable to historical flows, they are vulnerable in 50 to 75 percent of traces in the Drying with Variability Ensemble, regardless of the depletion demand scenario. The remaining alternatives may or may not be vulnerable, as they are vulnerable to about 50 percent of traces in the Drying with Variability Ensemble but not under historical conditions.

I.4 Summary and Conclusions

This sensitivity analysis examined how sensitive the different alternatives are to different Upper Basin depletion demand assumptions. Differences in Lower Basin demands are already represented through the alternatives' different shortage and surplus provisions. Multiple Upper Basin depletion demand scenarios, including steady-state demand levels ranging from 4.5 maf to 6.0 maf, were

evaluated in all hydrologic scenarios for all alternatives and the CCS Comparative Baseline. The Upper Basin modeled depletions and modeled shortages, impact on system conditions, robustness, and vulnerability were compared to evaluate their sensitivity to Upper Basin demand assumptions.

Across nearly all alternatives and performance metrics, lower Upper Basin steady-state depletion demand scenarios (e.g., 4.5 maf) resulted in higher elevations at Lake Powell and Lake Mead, greater 10-year Lee Ferry volumes, and smaller Lower Basin shortages compared to higher steady-state depletion demand scenarios. Consistent with these results, the Steady State 4.5 maf scenario resulted in the highest robustness at maintaining Lake Powell above elevation 3,500 feet and Lake Mead above elevation 975 feet, whereas the Steady State 6.0 maf scenario resulted in the lowest robustness.

The CCS Comparative Baseline, No Action, Basic Coordination, and Enhanced Coordination, Alternatives each showed relatively little variation in robustness and vulnerability across the different Upper Basin depletion demand scenarios. These alternatives consistently showed only minor changes in robustness scores and in the drought severity associated with vulnerability (differences in vulnerability thresholds typically range from 0.0 to 0.5 maf), indicating that their performance is less sensitive to assumed Upper Basin depletion demands than that of the other alternatives.

The Maximum Operational Flexibility Alternative followed similar trends to the CCS Comparative Baseline, No Action, Basic Coordination and Enhanced Coordination Alternatives except when considering the vulnerability at Lake Powell. Like the other alternatives, vulnerability thresholds for the Maximum Operational Flexibility Alternative changed modestly across the lower depletion demand scenarios, but changed sharply at the 6.0 maf depletion demand scenario. However, this sensitivity is likely due to the high robustness scores exhibited by this alternative (86 to 94 percent), which can make it difficult to identify and compare vulnerability thresholds.

The Supply Driven Alternative (LB Priority approach) behaved differently from all others. Because releases from Lake Powell are fixed at 65 percent of the preceding 3-year average natural flow, Lake Powell releases are typically the same for all depletion demand scenarios. As a result, at Lake Powell, robustness exhibited the largest spread of any alternative (a 30 percent range between Steady State 4.5 and 6.0 maf scenarios), and vulnerability thresholds varied by a 0.7 maf range. In contrast, at Lake Mead, both robustness and vulnerability were nearly identical across all depletion demand scenarios, making the Supply Driven Alternative the least sensitive alternative at Lake Mead to Upper Basin depletion demand assumptions.

The Representative Preferred Alternative exhibited a larger range in robustness across the depletion demand scenarios at Lake Powell (a 14 percent range between the Steady State 4.5 and 6.0 maf scenarios), second only to the Supply Driven Alternative (LB Priority approach), indicating a greater degree of sensitivity to the depletion demand scenarios. At Lake Mead, the range of vulnerability thresholds was lower than other alternatives except for the Supply Driven Alternative (LB Priority approach), showing a 0.2 maf difference between the Steady State 4.5 maf and 6.0 maf depletion demand scenarios. However, robustness scored varied from 49 to 61 percent across the depletion demand scenarios, a range similar to the other action alternatives except Supply Driven (LB Priority approach).

For all alternatives, different depletion demand scenarios did not change conclusions when comparing vulnerability thresholds to the Reference Hydrology. For Lake Powell, all alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives are reasonably likely to experience at least one occurrence below elevation 3,500 feet. For Lake Mead, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Priority) Alternatives may or may not be vulnerable to elevations below 975 feet because they are vulnerable in about 50 percent of traces in the Drying with Variability ensemble. In contrast, the CCS Comparative Baseline, No Action Alternative, and Basic Coordination Alternative are reasonably likely to experience elevations below 975 feet.

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Appendix J

Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
EIS	environmental impact statement
kaf	thousand acre-feet
LROC	Long-Range Operating Criteria
maf	million acre-feet
UCRC	Upper Colorado River Commission

Appendix J. Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage

J.1 Introduction

The No Action, Basic Coordination, and Representative Preferred Alternatives incorporate storage equalization operations, which include modeling assumptions regarding the 602(a) storage requirement in Lake Powell. Pursuant to the Long-Range Operating Criteria (LROC), annual releases from Lake Powell greater than the minimum objective release occur when Upper Basin storage is greater than the storage required by 602(a) storage, and the storage in Lake Powell is forecast to be greater than the storage in Lake Mead by the end of that water year. Under these conditions, additional releases are made from Lake Powell to equalize the storage in Lake Mead with the storage in Lake Powell by the end of the water year.

The 602(a) storage requirement specifies the amount of storage in Upper Basin reservoirs necessary to assure deliveries to the Lower Basin without impairment to the annual consumptive use in the Upper Basin. If the 602(a) storage requirement is not met, equalization does not occur. The LROC specifies that all relevant factors including historic stream flows, the most critical period of record, the probabilities of water supply, and estimated future depletions be considered when determining the 602(a) storage amount. Calculating the 602(a) storage based on these factors depends on values for several parameters including assumed future Upper Basin water demands, historical natural flow, the magnitude and duration of a critical period flow, and the percent shortage in the Upper Basin during the critical period.

This appendix provides a brief overview of the 602(a) storage requirement and the numerical equation used to calculate the required storage volume. It also provides updated data on Upper Basin water demands and the historical natural flow record, reflecting changes since the 2007 Interim Guidelines. Finally, it analyzes how the 602(a) storage determination varies based on different variables such as ranges of critical period flow, lengths of critical period, and a range of assumed Upper Basin shortage percent during the critical period.

J.2 Description of 602(a) Storage Requirement

Appendix A, CRSS Model Documentation describes the implementation of the 602(a) storage requirement used in this Final EIS. Since 2004, the Interim 602(a) Storage Guideline (69 Fed. Reg. 28945) has been included in the Colorado River Simulation System (CRSS) and relies on parameter values from the 1994 FORTRAN-based CRSS. The algorithm estimates the amount of storage needed in the Upper Basin to ensure that both the minimum objective release and Upper Basin depletions can be met over a future period of n years, assuming inflows during that period match those observed during the most critical historical period.

The previously identified critical period for the Colorado River Basin occurred from 1953 to 1964, spanning 12 years. Inflows from this period are used in the 602(a) storage calculation.

At the start of each calendar year, the 602(a) storage requirement is calculated using the following formula (**Table J-1** describes each parameter):

$$602(a) = \{(UBDepletion + UBEvap)* (1 - percentShort/ 100) + minObjRel - criticalPeriodInflow\} * criticalPeriodLength + minPowerPoolStorage$$

Table J-1
Description of Parameters included in the 2007 Interim Guidelines 602(a) Storage Requirement Formula

602(a) Storage Parameters	Definition	Value from 2007 FEIS	Source Data
602(a)	the 602(a) storage requirement		
UBDepletion	the average over the next 12 years of the Upper Basin scheduled depletions	Depends on simulation start year	2007 Interim Guidelines, Appendix C – 1999 Upper Colorado River Commission Depletion Demand Schedule
UBEvap	the average annual evaporation loss in the Upper Basin	560 kaf	Value from CRSS Cyber mainframe
percentShort	the percent shortage applied to Upper Basin depletions during the critical period	0%	Value from CRSS Cyber mainframe
minObjRel	the minimum objective release to the Lower Basin	8.23 maf	1970 Long-range Operating Criteria
criticalPeriodInflow	average annual natural inflow into the Upper Basin during the critical period (1953–1964)	12.18 maf	From WY 1953-1964 Natural Flow dated 6.22.07
criticalPeriodLength	number of years of the critical period (1953-1964)	12	Based on above period
minPowerPoolStorage	the cumulative amount of minimum power pool storage to be preserved in Upper Initial Unit reservoirs	5.179 maf	Value from CRSS Cyber mainframe

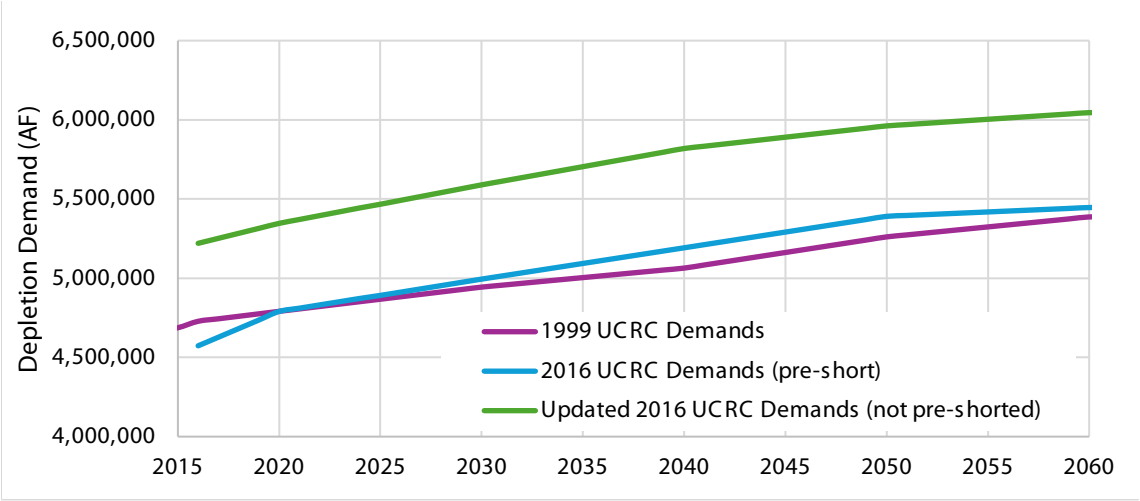
To facilitate further exploration of 602(a) storage requirement sensitivity, an extension of the current equalization line in CRSS was based on the same source data (shown above) originally used for 2007 Interim Guidelines equalization line estimation. To better understand the equalization line sensitivity to variations in specific parameters the following parameters were updated to use the latest available version of that parameter, Upper Basin depletion schedule and annual natural flow; or varied across

a range of potential values, critical period inflow and length, and percent shortage, to understand the impact on the computed 602(a) storage.

J.3 Upper Basin Depletion Schedule

The Upper Basin depletion schedule titled the Updated 2016 Upper Colorado River Commission (UCRC) depletion demand schedule, further described in **Appendix L**, Upper Division States Depletion Schedules, replaces the 1999 UCRC depletion demand schedule used during the 2007 Interim Guidelines. The 1999 UCRC schedule pre-shorted depletions because a portion of depletion demands could not be met in the high Upper Basin tributaries that were not represented in the previous version of CRSS. The latest CRSS (version 6) now incorporates methods to apply high tributary shortage directly in CRSS and uses the Updated 2016 UCRC depletion demand schedule. **Figure J-1** compares the Updated 2016 UCRC demands, the 2016 UCRC demands that include pre-shorted values, and the 1999 UCRC demands used in the 2007 Interim Guidelines.

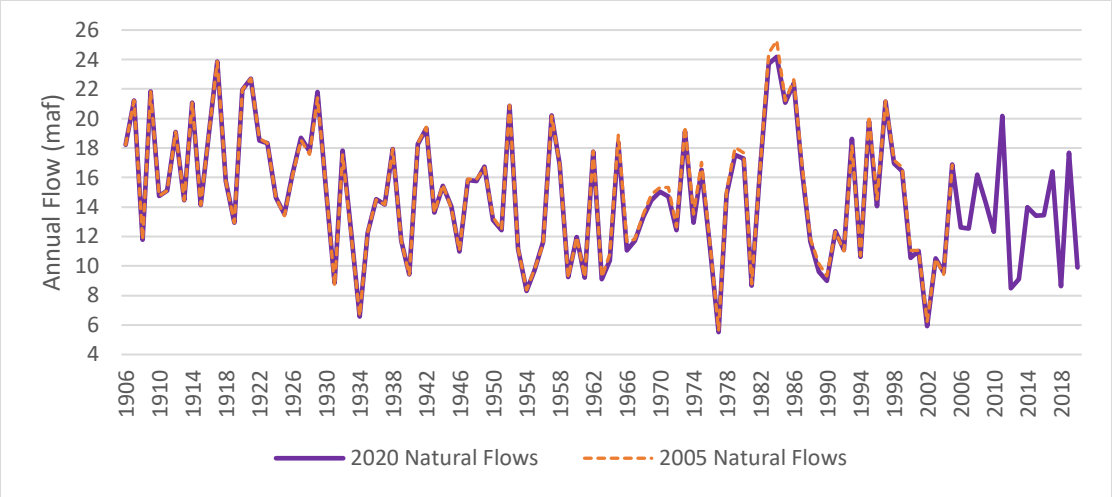
Figure J-1
Comparison of UCRC Depletion Demand Schedules (excludes CRSP Evaporation)



J.4 Annual Natural Flow

The latest official natural flow dataset, released December 15, 2022, spans 1906-2020 and replaces the June 22, 2007 natural flow record used during the 2007 Interim Guidelines that spanned 1906-2005. Many incremental changes have been applied since that release, but these only resulted in minor changes (see **Figure J-2**) to the overlapping record.

Figure J-2
WY Colorado River at Lees Ferry Natural Flow Comparison



J.5 Critical Period Inflow and Length

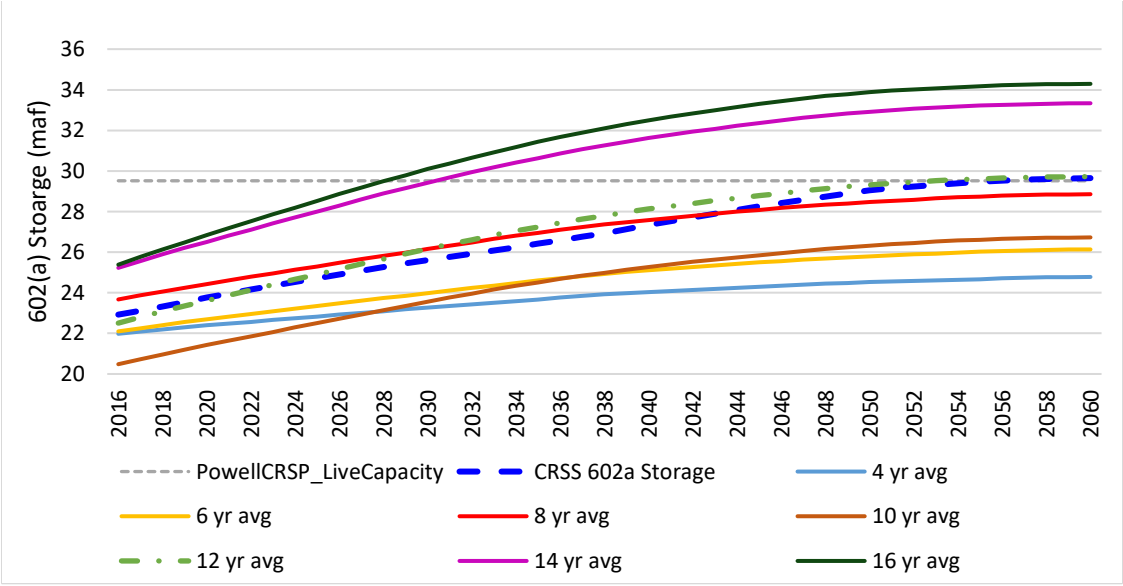
The critical period inflow and length parameters are determined from an analysis of the available natural flow record. Using the 1906-2020 natural flow record the critical period average inflow was computed for different critical period lengths, ranging from four to 20 years (**Table J-2**).[1] The 12-year critical period is still the 1953-1964 period, though the average inflow decreased by 0.05 maf due to the minor, incremental changes that have been applied to the natural flow record since 2005.

Figure J-3 shows the 602(a) storage given critical period lengths of 4, 6, 8, 10, 12, 14, and 16 years based on the 1906-2020 natural flow record and the Updated 2016 UCRC demand schedule with an assumed 10 percent shortage compared to the 602(a) storage requirement computed for the 2007 Interim Guidelines ("CRSS 602[a] Storage" long dashed royal blue line). The 602(a) storage for the 2007 Interim Guidelines used the 1906-2005 natural flow 12-year critical period (1953-1964) inflow of 12.18 maf from the CRSS Cyber mainframe values and the 1999 UCRC pre-shorted demand schedule. Except where otherwise noted, all other parameter values are consistent for all of the computed 602(a) storage requirements in **Figure J-3** and listed in **Table J-1**.

Figure J-3 shows that both the inflow volume and the duration of the critical period have a significant impact on the 602(a) storage requirement. However, it is important to note that the selection of the critical period is not straightforward, and there are no clearly defined or objective criteria available to guide this choice.

[1] The critical period average inflow is the minimum average inflow over a specified critical period length using the updated natural flow record (1906-2020).

Figure J-3
602(a) Storage Values across Various Critical Periods based on Updated Natural Flow and Upper Basin Demands with 10 Percent Shortage



Note: CRSS 602(a) Storage line continues to use the 12-year 1953-1964 period with a 12.18 maf critical period inflow from the original CRSS Cyber mainframe values.

Table J-2
Critical Period Lengths, Inflow, and Years Spanned

Critical Period Length (years)	Critical Period Inflow (maf)	Years in Record- 2020 NF
4	9.27	2001-2004
5	9.53	2000-2004
6	10.68	1999-2004
7	11.02	2000-2006
8	11.22	2000-2007
9	11.77	2000-2008
10	12.02	2000-2009
11	12.05	2000-2010
12	12.13	1953-1964

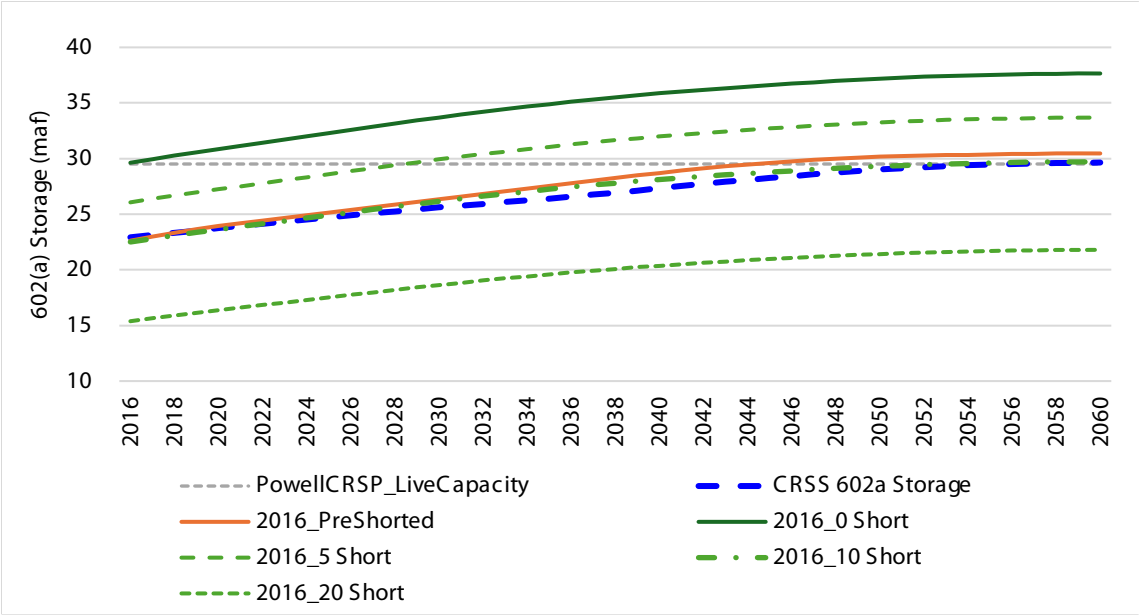
Critical Period Length (years)	Critical Period Inflow (maf)	Years in Record- 2020 NF
13	12.28	2001-2013
14	12.16	2000-2013
15	12.29	2000-2014
16	12.36	2000-2015
17	12.43	2000-2016
18	12.54	2001-2018
19	12.44	2000-2018
20	12.64	1999-2018

J.6 Critical Period Percent Shortage

To isolate the effect of the percent shortage parameter on 602(a) storage the Upper Basin depletion percent shortage varied between 0, 5, 10, and 20 percent. The 12-year critical period calculated from the updated natural flow, highlighted green in **Table J-2**, was held the same.

Figure J-4 compares the 602(a) storage computed using these different percent shortage parameter values and the Updated 2016 UCRC demands to the 602(a) storage computed using 0 percent shortage with the 2016 UCRC pre-shorted demands and the 602(a) storage requirement computed for the 2007 Interim Guidelines ("CRSS 602[a] Storage" long dashed royal blue line).[2] As with the choice of critical period inflow and length the assumed percent shortage during the critical period also exhibits significant impact on the calculated 602(a) storage volume. The Updated 2016 UCRC depletion demand schedule with a 10 percent Upper Basin shortage results in a similar 602(a) storage value to both the 2016 UCRC pre-shorted demand schedule and the 602(a) storage requirement computed for the 2007 Interim Guidelines.

Figure J-4
602(a) Storage Values across Various Upper Basin Depletion Percent Shortages



Note: CRSS 602(a) Storage lines continues to use the 12-year 1953-1964 period with a 12.18 maf critical period inflow from the original CRSS Cyber mainframe values.

J.7 Discussion

The 602(a) storage refers to the quantity of water required to be in storage in the Upper Basin so as to assure future deliveries to the Lower Basin without impairing annual consumptive uses in the Upper Basin. Its calculation depends on several inputs—most notably the assumed future Upper Basin demands, the selected "critical period," and the assumed level of Upper Basin shortage during that period.

Updating these inputs with the most recent information is sensible, but it also highlights how the time period affects the calculation. For example, using the full 1906–2020 natural flow record only

[2] The 602(a) storage for the 2007 Interim Guidelines uses the 1906-2005 natural flow 12-year critical period (1953-1964) inflow of 12.18 maf from the CRSS Cyber mainframe values and the 1999 UCRC pre-shorted demand schedule.

slightly changes the 12-year critical-period average inflow (12.13 maf vs. 12.18 maf using the 1906–2005 record). But the *choice of the critical period itself* has a much larger effect, and there is no objective standard for selecting it. A 12-year period with 12.13 maf average inflow is not necessarily more or less "critical" than a 10-year period averaging 12.02 maf or a 14-year period averaging 12.16 maf, yet each produces a different 602(a) requirement.

Assumptions about future Upper Basin demands introduce similar sensitivities. The 2007 calculation assumed zero Upper Basin shortage during the critical period because it relied on pre-shorted demand schedules. Because the Updated 2016 UCRC demand schedules no longer include pre-shorting, the zero-shortage assumption may no longer be appropriate—and it meaningfully affects the storage requirement.

Overall, this analysis shows that the 602(a) storage requirement varies substantially depending on the choices made for these key parameters. The 602(a) storage used in the 2007 Interim Guidelines generally falls near the middle of the range produced by the different tested assumptions.

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Appendix K

Sensitivity Analysis – Effects of Modeling Assumptions with Regard to Future Water Deliveries to Mexico

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Attachment

A Verification of Equal Proportional Reductions to United States and Mexico for Methodology A and Methodology B

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
EIS	environmental impact statement
IBWC	International Boundary and Water Commission
maf	million acre-feet
Reclamation	Bureau of Reclamation
U.S.	United States

Appendix K. Sensitivity Analysis – Effects of Modeling Assumptions with Regard to Future Water Deliveries to Mexico

K.1 Introduction

The proposed federal action includes the adoption of specific interim guidelines for Lower Basin shortages. The interim guidelines would be used by the Secretary to determine those circumstances under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead to the Colorado River Lower Division States (Arizona, California, and Nevada) (**Section 1.8.2.2**) below 7.5 million acre-feet (maf) (a "Shortage") pursuant to Article II(B)(3) of the Consolidated Decree. The determination of deliveries to Mexico is not a part of the proposed federal action. Any such determination would be made in accordance with the United States (U.S.)-Mexico Treaty on Utilization of Water of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty). Nevertheless, modeling assumptions with respect to the distribution of shortages for the Lower Division States include water delivery reductions to Mexico in order to analyze potential impacts on hydrologic and other environmental resources (**Section K.2** and **Appendix A**, CRSS Model Documentation).[1] These modeling assumptions were applied to the No Action Alternative as well as the action alternatives, i.e., the modeling assumptions with regard to the distribution of shortages to the Lower Division States include water delivery reductions to Mexico and are distributed proportionally in all alternatives.[2]

This appendix provides a comparative analysis of the sensitivity of the hydrologic resources to different modeling assumptions with regard to how Mexico would be affected by future water delivery reductions. Two methodologies for computing future water delivery reductions to Mexico, for modeling purposes, are described. The modeling assumptions used to implement the methodologies are also presented.

[1] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission (IBWC) in consultation with the Department of State.

[2] The Continued Current Strategies Comparative Baseline includes reductions and contributions for Mexico per Minute 323, which differ from the assumptions used in the No Action Alternative and action alternatives.

K.2 Description of Methodologies

Although many possible methodologies exist that would result in different volumes of potential future water delivery reductions to Mexico, two methodologies were considered in this analysis to assess the sensitivity of the hydrologic resources to a wide range of possible water delivery reductions.[3] Both methodologies are similar and both assume that the water deliveries to Mexico would be reduced in the same proportion as reductions in consumptive uses in the U.S. (shortages). The difference between the methodologies is whether shortages in both the Upper Basin and Lower Basin in the U.S. are considered when applying water delivery reductions to Mexico. Methodology A applies water delivery reductions to Mexico only when shortages to U.S. users in the Lower Basin occur, and water deliveries to Mexico are reduced in the same proportion as the reduction to U.S. users in the Lower Basin. This is the methodology that was used for the resource analyses in Volumes I and III of this Final EIS. Methodology B applies water delivery reductions to Mexico when shortages to U.S. users in either the Upper Basin or Lower Basin or both occur, and water deliveries to Mexico are reduced in the same proportion as the reduction to U.S. users in both the Upper and Lower Basins. These methodologies are described below along with comparisons of the results of the methodologies.

K.2.1 Methodology A

Under Methodology A, water delivery reductions to Mexico are triggered only when deliveries to U.S. users in the Lower Basin are reduced. When triggered, the water deliveries to Mexico are reduced in the same proportion as the reduction to the U.S. users in the Lower Basin. The methodology is as follows:

1) Look-up the total Lower Basin shortage. Under the Representative Preferred Alternative, shortages of specific magnitudes are triggered by specific Lake Mead elevations.
    - Example: for the Representative Preferred Alternative, if Lake Mead elevation is between elevations 1,125 and 1,025 feet, the total Lower Basin shortage is 1.5 maf

2) Compute the water delivery reduction to Mexico by multiplying the total Lower Basin shortage by 16.67 percent. This percentage is computed by taking the ratio of Mexico's allotment to the sum of the Lower Basin U.S. apportionments and Mexico's allotment (1.5 maf/(7.5 maf + 1.5 maf) = 0.1667 or 16.67 percent) and ensures that the water delivery reductions to Mexico are always proportional to the shortages to the U.S. users in the Lower Basin.
    - Example: assuming the total Lower Basin shortage is 1.5 maf, the water delivery reduction to Mexico would be computed as:

        *1.5 maf * 16.67 percent = 0.25 maf*

[3] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

A summary of shortages to U.S. users in the Lower Basin and water delivery reductions to Mexico for four example volumes of total Lower Basin shortage under the Representative Preferred Alternative is provided in **Table K-1** and **Table K-2**, respectively.

Table K-1
Example Shortages to United States Users in the Lower Basin for Methodology A

Lake Mead Effective Elevation (feet)	Total Lower Basin Shortage (maf)	Shortage to United States Lower Basin Users (maf)	Percent Reduction to United States Lower Basin Users	Total U.S. Delivery (maf)
1,135	0.75	0.625	8.3	6.875
1,125 to 1,025	1.50	1.250	16.7	6.250
1,000	2.55	2.125	28.3	5.375
Less than 975	3.60	3.000	40.0	4.500

Table K-2
Example Water Delivery Reductions to Mexico for Methodology A

Lake Mead Effective Elevation (feet)	Total Lower Basin Shortage (maf)	Reduction to Mexico (maf)	Percent Reduction to Mexico	Total Delivery to Mexico (maf)
1,135	0.75	0.125	8.3	1.375
1,125 to 1,025	1.50	0.250	16.7	1.250
1,000	2.55	0.425	28.3	1.075
Less than 975	3.60	0.600	40.0	0.900

Note: Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

K.2.2 Methodology B

Under Methodology B, water delivery reductions to Mexico are triggered by shortages to U.S. users in the Upper Basin, in the Lower Basin, or both. When triggered, the water deliveries to Mexico are reduced in the same proportion as the reduction to U.S. users in both the Upper and Lower Basins. The methodology is as follows:

1) Look-up the shortage to be applied to U.S. users in the Lower Basin.
    - Example: for the Representative Preferred Alternative, if Lake Mead elevation is between 1,125 and 1,025 feet, the shortage to U.S. users in the Lower Basin is 1.250 maf (**Table K-1**)

2) Compute the modeled shortage to U.S. users in the Upper Basin. Modeled shortages to U.S. users in the Upper Basin are assumed to occur when the delivery to those users is less than their depletion demand and is calculated as Upper Basin depletion demand minus Upper Basin modeled use (see **Section K.3.1** for more details).
    - Example: in the year 2030, the Upper Basin depletion demand is 5.534 maf and under one hydrologic sequence, The Colorado River Simulation System (CRSS) computed a delivery of 4.427 maf, resulting in a shortage to U.S. users in the Upper Basin of 1.107 maf, in addition to the shortage to U.S. users in the Lower Basin of 1.250 maf[4]

3) Compute the proportional reduction to U.S. users in both the Upper and Lower Basins as the sum of shortages to U.S. users in the Upper and Lower Basin divided by the sum of the Upper Basin scheduled use and the total U.S. Lower Basin apportionments (7.5 maf).
    - Example: the proportional reduction to the U.S. users would be computed as:

$$(1.250\ maf + 1.107\ maf) / (7.5\ maf + 5.534\ maf) = 18.1\ percent$$

4) Compute water delivery reduction to Mexico by applying the same proportional reduction to U.S. users in both the Upper and Lower Basins to Mexico. This is computed by multiplying Mexico's annual Colorado River allotment (1.5 maf) by the proportional reduction to U.S. users in both the Upper and Lower Basins.
    - Example: given the proportional reduction to U.S. users in both the Upper and Lower Basins is 18.1 percent, the water delivery reduction to Mexico would be computed as:

$$1.5\ maf * 18.1\ percent = 0.271\ maf$$

Since Upper Basin depletion demand varies each year (**Appendix L**, Upper Division States Depletion Schedules) and the computed shortages in the Upper Basin vary for each hydrologic sequence, a wide range of possible proportional reductions are simulated by Methodology B (from 4 percent to approximately 53 percent resulting in water delivery reductions to Mexico of approximately 0.065 to 0.791 maf as shown in **Figure K-3**).

Table K-3 shows some examples based on assumed Upper Basin modeled shortage, which fall within the range of actual modeled Upper Basin shortage (see **Section K.3.1**). The examples in **Table K-2** use an Upper Basin depletion demand of 5.835 maf (the average depletion demand over the 2027-2060 modeling period), resulting in the proportional reduction to the U.S. equal to the sum of Upper and Lower Basin U.S. shortages divided by 13.335 maf (7.5 maf plus 5.835 maf).

[4] The computed annual Upper Basin shortage in CRSS is not available until the end of the calendar year. In this example, the 2030 shortage would be used to set the 2031 water delivery reductions to Mexico.

Table K-3
Examples of Shortages to United States Users in the Upper and Lower Basins and Water Delivery Reductions to Mexico for Methodology B

Lake Mead Effective Elevation (feet)	Shortage to Lower Basin (maf)	Example Modeled Upper Basin Shortage (maf)	Total Shortage to United States (maf)	% Reduction to United States*	Reduction to Mexico Delivery (maf)**	% Reduction to Mexico
above 1,145	0.0	0.2	0.2	1.5	0.022	1.5
		1.4	1.4	10.5	0.157	10.5
		2.5	2.5	18.7	0.281	18.7
1,125 to 1,025	1.25	0.2	1.45	10.9	0.163	10.9
		1.4	2.65	19.9	0.298	19.9
		2.5	3.75	28.1	0.422	28.1
below 975	3.00	0.2	3.20	24.0	0.360	24.0
		1.4	4.40	33.0	0.495	33.0
		2.5	5.50	41.2	0.619	41.2

* Percent reduction to U.S. based on average depletion demand in the Upper Basin (5.835) and the Lower Basin apportionment (7.5 maf): 5.835 maf + 7.5 maf = 13.335 maf)
** Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

K.3 Modeling Results

An analysis was performed to test the sensitivity of the hydrologic resources to these two sets of modeling assumptions (Methodology A and B). The CRSS model was used to simulate water deliveries to Mexico under these two methodologies with all other modeling assumptions held constant. The modeling assumptions under the Representative Preferred Alternative were used for this assessment with one major exception. It was assumed that there was no storage and delivery mechanism in place in order to isolate the effects of each methodology. See **Appendix A**, CRSS Model Documentation, for detailed modeling assumptions. Results are presented using conditional boxplots, which separate results based on five flow categories (see **Section 3.2.6** for additional details on conditional boxplots).

K.3.1 Upper Basin Modeled Shortages

CRSS assumes that shortages in the Upper Basin occur only when there is not sufficient water available within a given reach to meet a user's demand. For purposes of this Final EIS analysis, the total Upper Basin modeled shortage for any year is computed as the total Upper Basin depletion subtracted from the Upper Basin depletion demand for that year. **Figure K-1** provides a conditional boxplot of Upper Basin modeled shortage generated by CRSS over the period 2027 through 2060. The computed shortages to the Upper Basin users are dependent solely upon the hydrologic sequences and are therefore identical under Methodology A and Methodology B.

Figure K-1
Annual Upper Basin modeled shortage

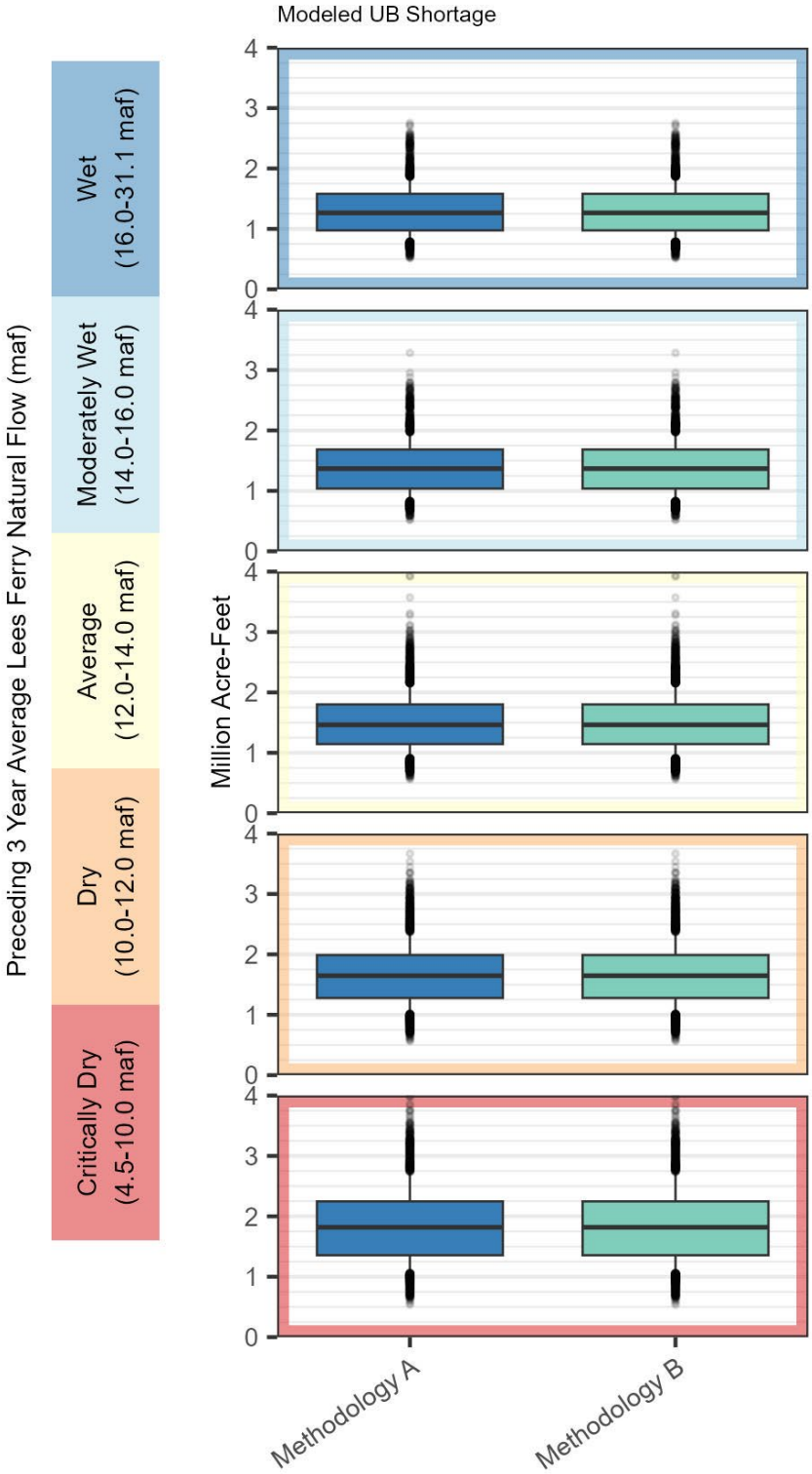


Figure K-1 shows that the Upper Basin modeled shortages range from 0.5 to 4.1 maf, with a modeled shortage occurring in all years. The Upper Basin modeled shortages generally increase in drier flow categories. In the Average Flow Category, the median Upper Basin modeled shortage is 1.5 maf, increasing to 1.6 and 1.8 maf in the Dry and Critically Dry Flow Categories, respectively. As a point of reference, a 1.5 maf Upper Basin modeled shortage represents approximately 26 percent of the average Upper Basin depletion demand during the modeled period.

K.3.2 Lake Powell and Lake Mead Water Surface Elevations

Figure K-2 compares the elevations at Lake Powell and Lake Mead under Methodology A and B. Lake Powell elevations are nearly the same under Methodology A and Methodology B because Lake Powell inflow does not change with different assumptions for water delivery reductions to Mexico. Lake Powell release is generally based only on Lake Powell elevation, except at high elevations where equalization releases consider both Lake Powell and Lake Mead elevation (see **Appendix A**, CRSS Modeling Assumptions for additional details). While there are small differences in Lake Powell elevation between Methodology A and Methodology B in a small number of years at these higher elevations, there are no differences in the statistics shown in the conditional boxplots in **Figure K-2**.

There are small differences in Lake Mead elevations between Methodology A and Methodology B, with the elevations in Methodology B typically higher than those in Methodology A. In the Average Flow Category, the median Lake Mead elevation from Methodology B is approximately 5 feet higher than Methodology A (1,092 and 1,087 feet respectively). In both the Dry and Critically Dry Flow Categories, the median elevation is approximately 2 feet higher in Methodology B than in Methodology A. This is because Methodology B typically results in higher delivery reductions to Mexico than Methodology A (**Section K.3.3**), which results in higher Lake Mead elevations.

K.3.3 Comparison of Water Deliveries to Mexico

As described in **Section 4.2**, water deliveries to Mexico are assumed to be 1.5 maf, except when the model assumes that additional deliveries of up to 0.2 maf have been scheduled or a water delivery reduction has been incurred. Additional deliveries to Mexico of up to 0.2 maf are assumed to occur when Lake Mead is in flood control operations, under 70R Surplus Conditions, or in the assumed "Domestic" Surplus Conditions. A Domestic Surplus (up to 0.5 maf) is assumed to occur when the August 1 Lake Mead effective elevation is at or above 1,165 feet and Flood Control or 70R Surplus is not triggered. When triggered it is assumed that a proportional share (up to 83.35 thousand acre-feet) of the additional water deliveries is provided to Mexico (above 1.5 maf and not more than 1.7 maf total). Reductions in the water deliveries to Mexico are simulated consistent with the modeling assumptions described previously under each methodology. Consequently, simulated water deliveries to Mexico are expected to fluctuate throughout the analysis period (2027 through 2060) reflecting variations in hydrologic conditions under these assumptions.

Figure K-2
End-of-Water Year Lake Powell and End-of Calendar Year Lake Mead elevations

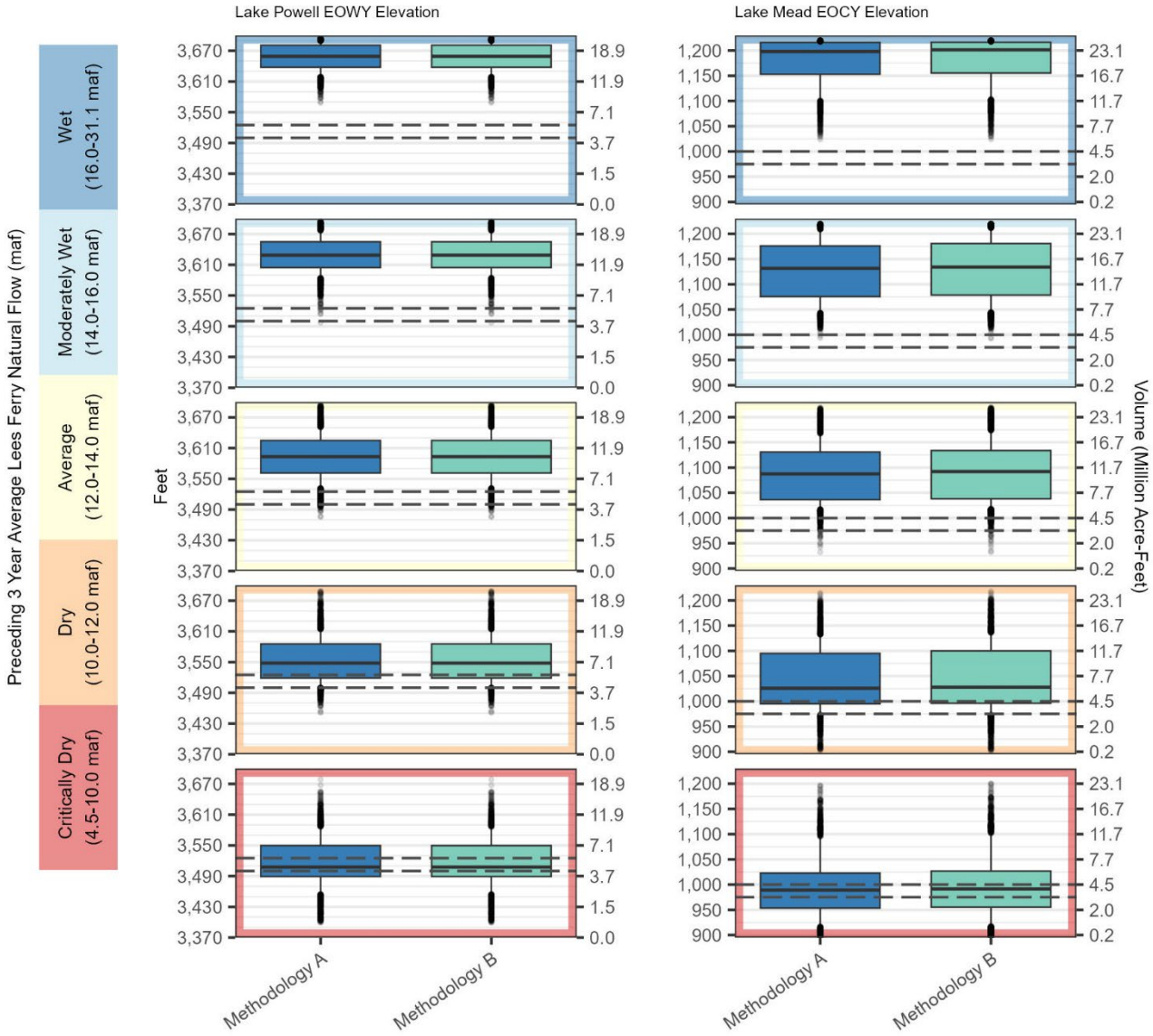
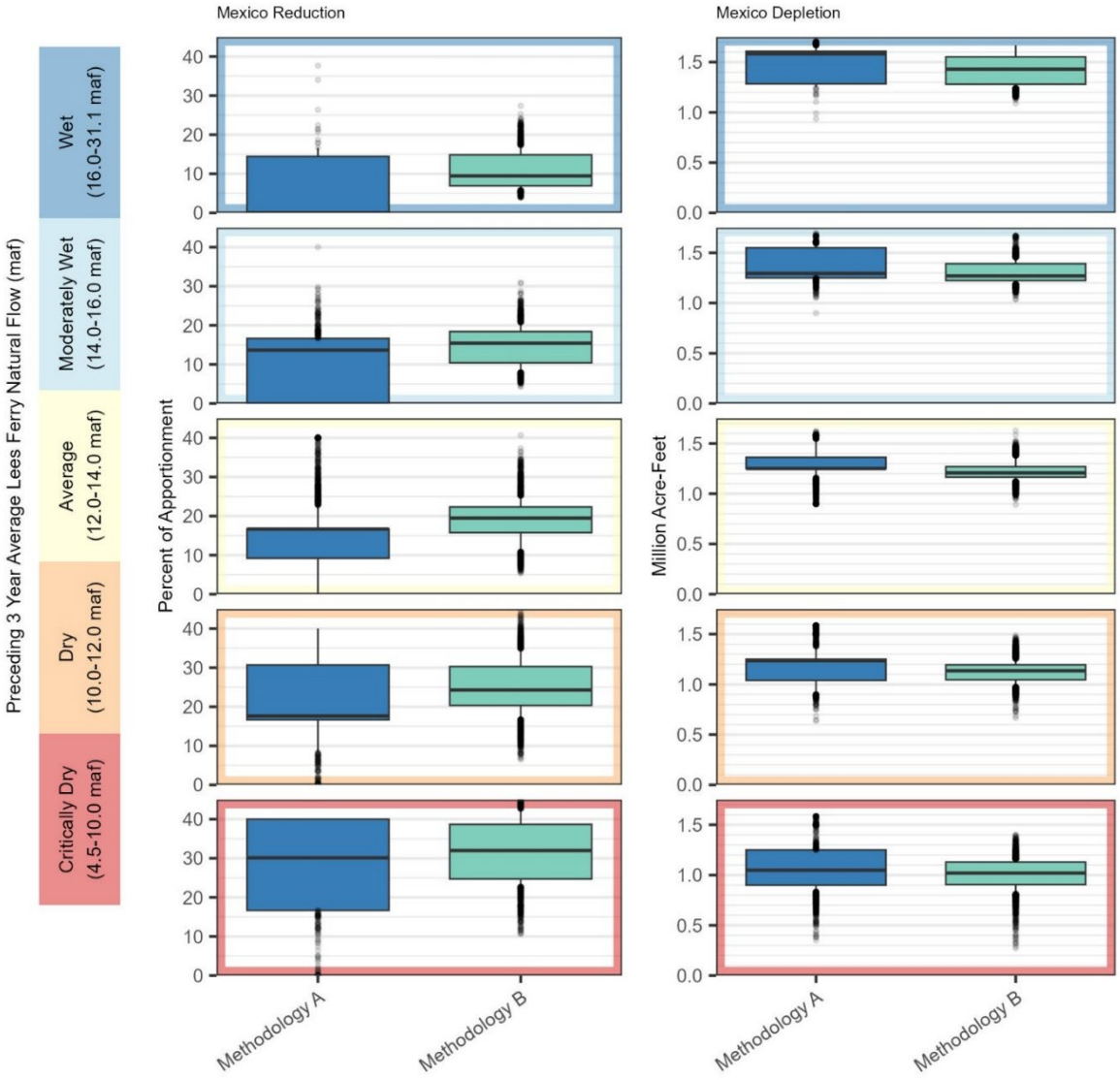


Figure K-3 compares the modeled water delivery reductions to Mexico (volumetrically and as a percent of Mexico's 1.5 maf allotment) and the total annual delivery to Mexico (Mexico depletion) for the two methodologies. Overall, in all flow categories, Methodology B results in higher delivery reductions and lower annual deliveries than Methodology A. **Figure K-3** shows that Methodology A has some years where there are no delivery reductions (e.g., at the 25th percentile in the Moderately Wet Category, and at the 10th percentile in the Average Flow Category), while Methodology B always has some delivery reductions. Additionally, Methodology A results in a maximum delivery reduction of 0.6 maf (or 40.0 percent of allotment), which corresponds to 16.67 percent of the maximum total Lower Basin shortage of 3.6 maf in the Representative Preferred Alternative. The maximum delivery reduction from

Methodology B ranges from 0.411 maf (27.4 percent of allotment) in the Wet Flow Category to 0.791 maf (52.7 percent of allotment) in the Critically Dry Flow Category. **Table K-4** and **Table K-5** report the water delivery reductions to Mexico for all flow categories as a percent of allocation and volumetrically, respectively. The higher overall reductions, higher maximum reductions, and larger range of reductions in Methodology B are because Upper Basin modeled shortages occur frequently and are included in the calculation of the proportional reduction under Methodology B.

Figure K-3
Annual delivery reductions and deliveries to Mexico



Note: The modeled annual delivery reductions and deliveries to Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table K-4
Water Delivery Reductions to Mexico (Percent of Allotment)

Scenario	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Representative Preferred (Method A)	16-31.1	37.7	16.7	14.4	0.0	0.0	0.0	0.0
Representative Preferred (Method A)	14-16	40.0	16.7	16.7	13.7	0.0	0.0	0.0
Representative Preferred (Method A)	12-14	40.0	22.9	16.7	16.7	9.2	0.0	0.0
Representative Preferred (Method A)	10-12	40.0	40.0	30.7	17.6	16.7	8.3	0.0
Representative Preferred (Method A)	4.5-10	40.0	40.0	40.0	30.1	16.7	16.7	0.0
Representative Preferred (Method B)	16-31.1	27.4	17.4	14.9	9.4	6.9	5.7	3.9
Representative Preferred (Method B)	14-16	30.9	20.8	18.4	15.5	10.4	8.0	4.3
Representative Preferred (Method B)	12-14	40.7	25.3	22.3	19.5	15.8	10.8	5.3
Representative Preferred (Method B)	10-12	49.7	34.9	30.3	24.3	20.3	16.8	6.5
Representative Preferred (Method B)	4.5-10	52.7	42.6	38.7	32.0	24.7	22.7	10.6

Note: The modeled delivery reductions to Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table K-5
Water Delivery Reductions to Mexico (Volumetric)

Scenario	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Representative Preferred (Method A)	16-31.1	0.565	0.250	0.217	0.0	0.0	0.0	0.0
Representative Preferred (Method A)	14-16	0.600	0.250	0.250	0.205	0.0	0.0	0.0
Representative Preferred (Method A)	12-14	0.600	0.343	0.250	0.250	0.138	0.0	0.0
Representative Preferred (Method A)	10-12	0.600	0.600	0.460	0.265	0.250	0.125	0.0
Representative Preferred (Method A)	4.5-10	0.600	0.600	0.600	0.452	0.250	0.250	0.0
Representative Preferred (Method B)	16-31.1	0.411	0.260	0.223	0.142	0.104	0.086	0.058
Representative Preferred (Method B)	14-16	0.463	0.311	0.276	0.232	0.156	0.119	0.065
Representative Preferred (Method B)	12-14	0.610	0.379	0.335	0.292	0.236	0.163	0.079
Representative Preferred (Method B)	10-12	0.745	0.523	0.454	0.364	0.305	0.251	0.097
Representative Preferred (Method B)	4.5-10	0.791	0.639	0.580	0.480	0.371	0.341	0.159

Note: The modeled delivery reductions to Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

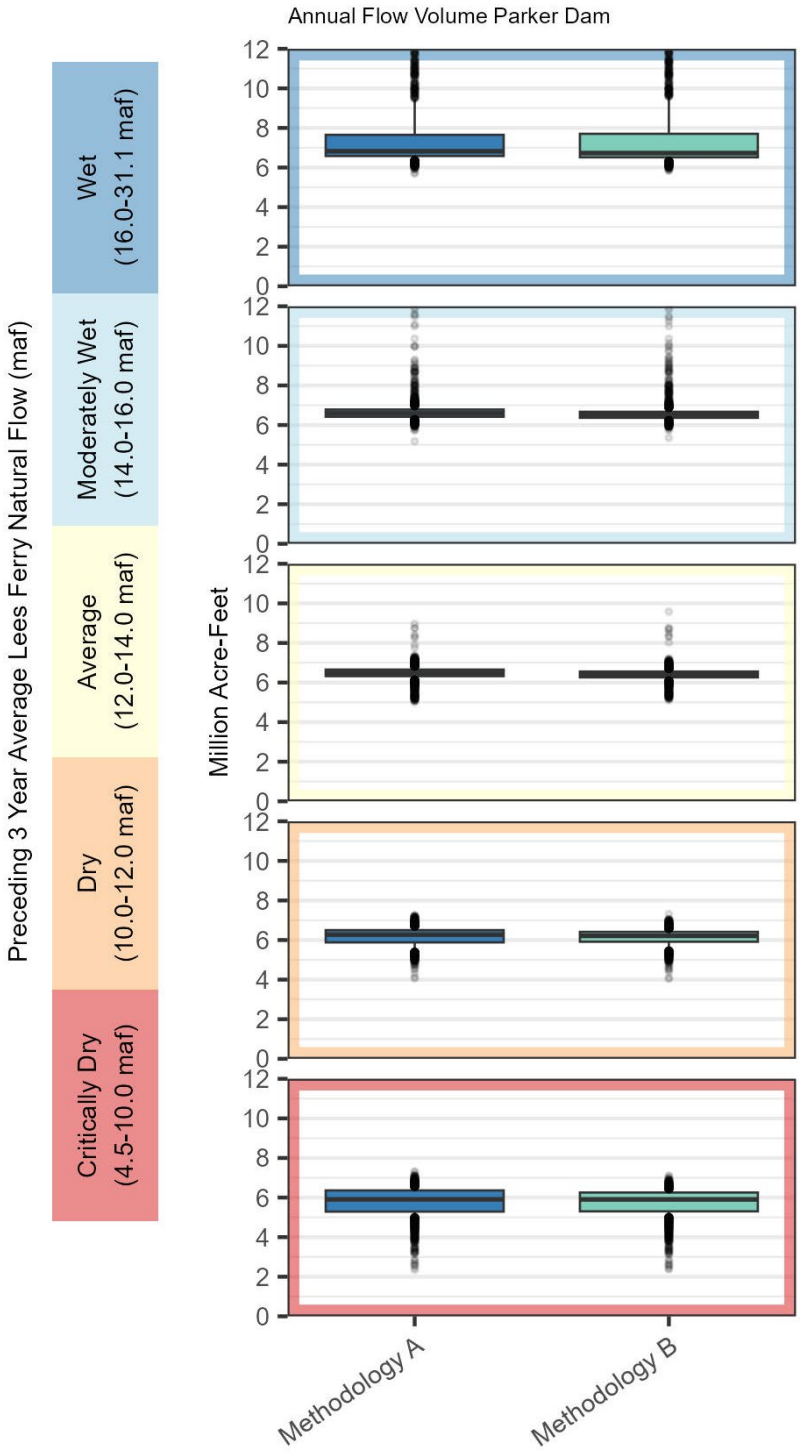
The annual delivery to Mexico (**Figure K-3**) shows similar information as the delivery reductions but incorporates years with additional deliveries to Mexico because of Flood Control, 70R, or Domestic Surplus, as previously discussed. Additionally, the annual deliveries incorporate years where the deliveries to Mexico are reduced beyond the specified reductions in Methodology A or B due to dead pool-related reductions (see **Section 3.4.2**, Issue 3 for an explanation of dead pool-related reductions). For example, the minimum annual delivery in the Critically Dry Flow Category in Methodology A is 0.350 maf. With a maximum delivery reduction of 0.60 maf, the minimum delivery due to the specified delivery reductions would be 0.9 maf; the difference between 0.350 maf and 0.9 maf is due to the dead pool-related reductions, which occur when Lake Mead approaches dead pool. Conversely, the maximum annual delivery to Mexico is 1.7 maf and 1.67 maf[5] in the Wet and Moderately Wet Flow Categories for Methodology A and Methodology B, respectively, and reflects the additional deliveries to Mexico above their 1.5 maf allocation. Overall, the annual deliveries to Mexico are lower in Methodology B than in Methodology A, for the same reasons that the reductions are higher, as previously discussed.

K.3.4 Parker Dam Releases

The flows in the river from Parker Dam to Imperial Dam result primarily from the controlled releases from Parker Dam. **Figure K-4** compares the releases from Parker Dam. There are only small differences in the annual releases from Parker Dam between Methodology A and B. In the Average Flow Category, the median Parker Dam release is 6.48 maf in Methodology A and 6.41 maf in Methodology B; in the Dry Flow Category Methodology A is 6.27 maf and Methodology B is 6.21 maf; in the Critically Dry Flow Category Methodology A is 5.91 maf and Methodology B is 5.91 maf. Methodology B produces lower releases in all flow categories across nearly all boxplot statistics, consistent with earlier findings showing greater delivery reductions to Mexico—and therefore lower releases from Parker Dam.

[5] The maximum annual delivery to Mexico is 1.7 maf based on the 1944 Water Treaty. CRSS constrains the available additional delivery volume to Mexico to 200 thousand acre-feet (1.7 maf minus 1.5 maf). It then computes the total delivery to Mexico as 1.5 maf plus additional deliveries minus reductions. Because Methodology B always has a non-zero reduction, the total delivery always results in a number smaller than 1.7 maf. If the CRSS logic was implemented differently, by not constraining the available additional delivery water and instead constraining the total delivery, the total delivery to Mexico under Methodology B could be as high as 1.7 maf. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

Figure K-4
Flow Conditioned Box Plot of Parker Releases



Attachment A

Verification of Equal Proportional Reductions to United States and Mexico for Methodology A and Methodology B

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Attachment A. Verification of Equal Proportional Reductions to United States and Mexico for Methodology A and Methodology B

Both Methodology A and Methodology B assume that the water deliveries to Mexico would be reduced in the same proportion as reductions in consumptive uses in the U.S. (shortages). This attachment provides additional information with regard to equal proportional reductions.

Model Verification

In order to verify that the model was accurately computing equal proportional water delivery reductions to Mexico, output from the model was used to compute reductions for both the U.S. and Mexico as a percentage of the appropriate demand.[6] **Table Att. A-1** provides a comparison of these computed values using Methodology A and Methodology B for the U.S. and Mexico. **Table Att. A-1** verifies that under both methodologies, deliveries to Mexico are reduced in the same proportion as deliveries to the U.S.

[6] For Mexico, it is always the reduction divided by 1.5 maf. For the U.S., it is the Lower Basin shortage divided by 7.5 maf for Methodology A, and Lower Basin shortage plus Upper Basin modeled shortage divided by 7.5 maf plus the Upper Basin depletion demand for the year for Methodology B.

Table Att. A-1
Reduction in Deliveries to Mexico and U.S. Shortage as a percentage of demand

Scenario	Entity	Flow Category	Max	90%	75%	50%	25%	10%	Min
Representative Preferred (Method A)	Mexico	16-31.1	37.7	16.7	14.4	0.0	0.0	0.0	0.0
Representative Preferred (Method A)		14-16	40.0	16.7	16.7	13.7	0.0	0.0	0.0
Representative Preferred (Method A)		12-14	40.0	22.9	16.7	16.7	9.2	0.0	0.0
Representative Preferred (Method A)		10-12	40.0	40.0	30.7	17.6	16.7	8.3	0.0
Representative Preferred (Method A)		4.5-10	40.0	40.0	40.0	30.1	16.7	16.7	0.0
Representative Preferred (Method A)	United States Lower Basin users	16-31.1	37.7	16.7	14.4	0.0	0.0	0.0	0.0
Representative Preferred (Method A)		14-16	40.0	16.7	16.7	13.7	0.0	0.0	0.0
Representative Preferred (Method A)		12-14	40.0	22.8	16.7	16.7	9.2	0.0	0.0
Representative Preferred (Method A)		10-12	40.0	40.0	30.7	17.6	16.7	8.3	0.0
Representative Preferred (Method A)		4.5-10	40.0	40.0	40.0	30.1	16.7	16.7	0.0
Representative Preferred (Method B)	Mexico	16-31.1	27.4	17.4	14.9	9.4	6.9	5.7	3.9
Representative Preferred (Method B)		14-16	30.9	20.8	18.4	15.5	10.4	8.0	4.3
Representative Preferred (Method B)		12-14	40.7	25.3	22.3	19.5	15.8	10.8	5.3
Representative Preferred (Method B)		10-12	49.7	34.9	30.3	24.3	20.3	16.8	6.5
Representative Preferred (Method B)		4.5-10	52.7	42.6	38.7	32.0	24.7	22.7	10.6
Representative Preferred (Method B)	United States	16-31.1	27.4	17.4	14.9	9.4	6.9	5.7	3.9
Representative Preferred (Method B)		14-16	30.9	20.8	18.4	15.5	10.4	8.0	4.3
Representative Preferred (Method B)		12-14	40.7	25.3	22.3	19.5	15.8	10.8	5.3
Representative Preferred (Method B)		10-12	49.7	34.9	30.3	24.3	20.3	16.8	6.5
Representative Preferred (Method B)		4.5-10	52.7	42.6	38.7	32.0	24.7	22.7	10.6

Note: The modeled delivery reductions to Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Appendix L

Upper Division States Depletion Schedules

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Acronyms and Abbreviations

	Full Phrase
CRSS	Colorado River Simulation System
Reclamation	Bureau of Reclamation
UCRC	Upper Colorado River Commission
Upper Basin	Upper Colorado River Basin

Appendix L. Upper Division States Depletion Schedules

L.1 Overview of Methodology for Developing the Baseline Upper Division States Depletion Demand Schedules

The Upper Basin Colorado River Simulation System (CRSS) baseline demand schedules were developed from the Upper Colorado River Commission's (UCRC) updated 2016 Depletion Demand Schedule[1,2]. Specifically, the UCRC—in coordination with the Upper Division States—developed decadal projections of water depletion demands by sector at the state level to support long-term planning efforts. These projections represent anticipated water demands under assumed economic and hydrologic conditions. The Arizona portion of the Upper Colorado River Basin (Upper Basin) demand schedule was developed by the Bureau of Reclamation (Reclamation) and is primarily comprised of Navajo Nation uses. The representation of the Upper Basin Tribes in the UCRC depletion demand schedule was presented in documentation dated July 13, 2022, that outlines the differences between the 2018 Tribal Water Study demand schedules and the updated 2016 Depletion Demand Schedule[3,4].

To integrate the UCRC's decadal projections into CRSS, Reclamation worked with the Upper Division States to disaggregate the state-level demand estimates to CRSS' spatial resolution at an annual timestep. These annual depletion values were further disaggregated to a monthly timestep using sector and subbasin-specific monthly distribution coefficients, which were derived either from data provided by the Upper Division States or from average distributions based on Reclamation's Consumptive Use & Loss reports. Corresponding diversion values were subsequently calculated using the disaggregated depletion estimates and water-user-specific efficiency ratios. State level

[1] Upper Colorado River Commission (UCRC) & Upper Division States. (2022, June 14). *Combined Resolution and Updated 2016 Depletion Demand Schedule*. Upper Colorado River Commission. Retrieved from http://www.ucrcommission.com/wp-content/uploads/2022/06/UCRC-and-Upper-Division-States-Combined-Resolution-and-Updated-2016-Depletion-Demand-Schedule-June-14-2022-1.pdf.

[2] Neither the CRSS baseline demands nor the UCRC 2016 Depletion Demand Schedule include reservoir evaporation undistributed by state from Lake Powell, Flaming Gorge, Blue Mesa, Morrow Point, which averages 520.0 kaf per year.

[3] The Post-2026 modeling is based on water rights of the Ute Indian Tribe of the Uintah & Ouray Reservation that have not been ratified by all parties. The Ute Indian Tribe of the Uintah & Ouray Reservation has federally reserved Indian water rights, a portion of which were federally decreed in 1923 and a portion of which have been separately recognized and put to use by the United States and the State of Utah, which are not fully resolved.

[4] The information reflected in the baseline depletion demands schedule relies on information about projected future Tribal water demands. The projections were based on information compiled in a Colorado River Basin Ten Tribes Partnership Tribal Water Study (December 2018). As discussed in Chapter 8 of that Study, the technical approach was based on the best science and information available at the time, given limitations related to timeframes and resource constraints, among other things. The Navajo Nation informed Reclamation that it was developing updated projections as part of its water development planning. Reclamation worked with the Navajo Nation as needed to update demand schedules prior to the publication of the Final EIS.

reservoir evaporation for reservoirs explicitly represented in CRSS[5], which averages 56.0 thousand acre-feet per year, w removed from the UCRC's decadal projections before loading in CRSS but are included in the table below.

Table L-1 shows the depletion demands for the Upper Basin by state.

Table L-1
Upper Division States Depletion Demand Schedule (thousand acre-feet)

Calendar Year	Arizona[6]	Colorado	New Mexico	Utah	Wyoming	Total Upper Basin
2027	40	2,989	653	1,131	710	5,516
2028	40	2,998	657	1,141	712	5,541
2029	41	3,007	661	1,152	714	5,565
2030	41	3,016	665	1,162	716	5,590
2031	42	3,022	668	1,173	718	5,613
2032	42	3,029	671	1,185	720	5,636
2033	43	3,036	675	1,196	722	5,659
2034	43	3,043	678	1,206	724	5,680
2035	44	3,050	681	1,216	726	5,702
2036	44	3,057	685	1,228	728	5,726
2037	45	3,064	688	1,239	730	5,749
2038	45	3,071	691	1,251	731	5,772
2039	46	3,077	695	1,263	733	5,796
2040	46	3,084	698	1,274	735	5,819
2041	47	3,095	699	1,277	737	5,834
2042	47	3,105	699	1,277	739	5,847
2043	47	3,115	700	1,278	741	5,860
2044	47	3,126	700	1,279	742	5,873
2045	47	3,136	701	1,280	744	5,886
2046	47	3,147	702	1,280	746	5,899
2047	47	3,157	702	1,283	748	5,914
2048	47	3,167	703	1,286	749	5,930
2049	47	3,178	703	1,290	751	5,945
2050	47	3,188	704	1,293	753	5,961
2051	47	3,191	705	1,296	755	5,969
2052	47	3,195	705	1,299	757	5,978
2053	47	3,198	706	1,302	758	5,986
2054	47	3,202	707	1,305	760	5,994

[5] Reservoir evaporation distributed by state explicitly represented in CRSS includes Navajo, McPhee, Dillon, Granby, Homestake and Willow Creek reservoirs.

[6] In response to comments received on the Navajo Nation's demands used in the Draft EIS, the values presented in this table reflect updated demands. To fully incorporate the updated demands into the Final EIS analyses, all alternatives and resource models would have had to be re-run, which was not feasible within the given timeline. As such, all modeling and analyses included in this Final EIS still use the demands from the Draft EIS. A sensitivity analysis found that, while the updated demands result in minor changes, they would not significantly affect the relative ranking of alternatives or the conclusions for any resource.

Calendar Year	Arizona[6]	Colorado	New Mexico	Utah	Wyoming	Total Upper Basin
2055	47	3,205	707	1,308	762	6,003
2056	47	3,209	708	1,311	764	6,011
2057	47	3,212	709	1,314	765	6,020
2058	47	3,215	710	1,317	767	6,028
2059	47	3,219	710	1,320	769	6,036
2060	47	3,222	711	1,323	771	6,045

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Appendix M

Lower Division States Depletion Schedules

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CRSS	Colorado River Simulation System
Reclamation	Bureau of Reclamation

Appendix M. Lower Division States Depletion Schedules

M.1 Introduction

This appendix contains schedules of projected Colorado River system depletions[1] by the Lower Division States (Arizona, California, and Nevada). These schedules were used to model the operation of the Colorado River system under the No Action Alternative, the action alternatives, and the Continued Current Strategies Comparative Baseline. The schedules used to model depletions under Normal Conditions are included in this appendix and are input into the Colorado River Simulation System (CRSS). CRSS then adjusts the schedules to reflect shortage and Surplus Conditions, which vary by alternative and shortage distribution method (**Chapter 2**), as well as assumed conservation activities (**Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

The depletion schedules were developed by the Bureau of Reclamation (Reclamation) with review by the Lower Division States and tribes. This appendix documents the method Reclamation used to develop the depletion schedules and notes where adjustments to this method were made, based on input from the Lower Division States and tribes.

M.2 Methodology for Developing the Baseline Lower Division States Depletion Schedules

The baseline 2027-2060 depletion schedules were developed using a multi-step methodology that incorporates historical water use and efficiency data. First, the average of the three highest annual water use values from 2008–2022 was calculated to estimate each user's potential maximum use. Then, historical efficiency was determined as the ratio of depletion to diversion over the same period. Initial 2027 demands were set as the lesser of this average maximum use or the user's entitlement, with corresponding diversion or depletion values derived using the calculated efficiency. These initial demands are then linearly increased to full entitlement levels by 2040. For the junior water users Metropolitan Water District, Central Arizona Project, and Southern Nevada Water Authority, the depletion schedules are computed by subtracting other users' depletions from the state's apportionment. Several exceptions to this general process are addressed individually based on unique user circumstances.

[1] In this appendix, and in Colorado River Simulation System (CRSS) modeling generally, "depletion" and "consumptive use" are used synonymously and are defined as diversion minus return flow.

A detailed outline of this methodology is provided below. Annual depletion schedules will sum to each Lower Division State's apportionment. Note, if a water user has multiple priorities with the same service area, it is assumed water is diverted first under the senior priority followed by the more junior priorities.

1. **Average Historical Maximum Use**
    - Calculate the average of the three highest annual water use values from 2008-2022 using historical depletion and diversion data from Reclamation's Colorado River Accounting and Water Use Report: Arizona, California, and Nevada reports ("Water Accounting Reports"). This value represents a reasonable estimate of the user's potential maximum use for the upcoming year under existing conditions.
    - If three years of data were not available, the average was calculated using all available data within the specified period.
    - Unless otherwise noted, if a user has multiple water entitlements, the average historical maximum use for the junior water entitlement(s) is calculated as the average of the three highest annual water use values minus the estimated 2027 depletion for the senior water entitlement(s) (from step 3). This approach effectively assumes water has historically been diverted under the senior water entitlement(s) before the junior water entitlement(s).

2. **Average Historical Efficiency**
    - Calculate the historical average efficiency for 2008-2022 using diversion and depletion data from the Water Accounting Reports.

$$\boldsymbol{Efficiency} = \frac{\boldsymbol{Depletion}}{\boldsymbol{Diversion}}$$

    - If complete data for the period is unavailable, use all available data within the specified period.
    - If a water user has no historical diversion data, assume an efficiency of 1 unless additional information is available.
    - Round the resulting average efficiency to two decimal places.

3. **Initial (2027) Demand**
    - Calculate the initial (2027) demand—either depletion or diversion—as the minimum of:
        i. average maximum use (from step 1); or
        ii. the user's entitlement

- If the water user has a consumptive use entitlement, the initial depletion is the minimum of the average maximum historical depletion and the entitlement. The corresponding diversion equivalent is calculated using the historical average efficiency:

$$\boldsymbol{Diversion} = \frac{\boldsymbol{Depletion}}{\boldsymbol{Efficiency}}$$

- If the water user has a diversion entitlement, the initial diversion equals the minimum of the of the average maximum diversion and the diversion entitlement. The corresponding depletion is calculated using the historical average efficiency:

$$\boldsymbol{Depletion} = \boldsymbol{Diversion\ x\ Efficiency}$$

4. **Demand Buildout to Full Entitlement**
    - Use the initial demand estimate (from step 3) and linear interpolation to gradually increase the demand to full entitlement (diversion or depletion) by 2040.

5. **Approach for Junior Water Users**
    - For Metropolitan Water District (California), Central Arizona Project (Arizona), and Southern Nevada Water Authority (Nevada), the depletion is estimated by subtracting the total depletion of all other users from the State's apportionment.
    - The corresponding diversion is calculated using the historical average efficiency.

Disclaimer: Several exceptions apply to the general process, such as water users with both diversion and consumptive use entitlements, users with no history of use, and users with multiple water entitlements. These exceptions are handled on a case-by-case basis and noted on the applicable water users in the following section.

M.3 Lower Division States Depletion Schedules

Table M-1 through **Table M-6i** show the baseline depletion schedules for the modeled Lower Division State mainstream entitlement holders, which are consistent with those reported in Reclamation's Water Accounting Reports. The priorities of the CRSS users in Nevada and California are provided in their respective state tables, while Arizona users are organized into different tables by priority. The priority of each user is used to distribute shortage by priority in multiple alternatives. Note that the CRSS model structure does not include water uses that hold only surplus contracts or uses that would require water above each state's apportionment to satisfy. For surplus modeling assumptions, please see **Appendix A**, CRSS Model Documentation.

Table Number	Depletion Schedule
M-1	Nevada
M-2a through M-2c	California
M-3a through M-3c	Arizona Priority 1
M-4	Arizona Priority 2
M-5a through M-5d	Arizona Priority 3
M-6a through M-6i	Arizona Priority 4

Additionally, for some water users, the CRSS structure aggregates multiple real-world users. In those cases, the assumed priority used in CRSS and in figure labels may not match the priority of all users; the assumed priority is chosen as a modeling simplification. One example of this simplification occurs in the modeling for Nevada Priorities 5 and 6 users, which are included in Priority 8 because the Southern Nevada Water Project services these users. The shortage allocation model provides more detail on the distribution of shortages (**Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation).

Table M-1
State of Nevada Water Users (acre-feet)

Calendar Year	Southern Nevada water providers (P8) with Cons. Mechanism[1]	Southern Nevada water providers (P8) without Cons. Mechanism[2]	Laughlin M&I (P8)	NV DOW (P7)[3]	Lake Mead NRA (P2)	Lake Mead NRA (PPR[4]/P1)	Ft Mojave Indian Reservation (PPR/P1)	Total State of Nevada with Cons. Mechanism[5]	Total State of Nevada without Cons. Mechanism[6]
2027	213,888	293,542	2,205	12	203	500	3,538	220,346	300,000
2028	217,357	292,860	2,413	13	303	500	3,911	224,497	300,000
2029	220,826	292,178	2,620	14	403	500	4,285	228,648	300,000
2030	224,295	291,496	2,827	15	502	500	4,659	232,799	300,000
2031	227,764	290,814	3,035	16	602	500	5,033	236,950	300,000
2032	232,174	290,132	3,242	17	702	500	5,407	242,042	300,000
2033	236,583	289,451	3,449	18	802	500	5,781	247,132	300,000
2034	240,993	288,769	3,656	19	901	500	6,155	252,224	300,000
2035	245,403	288,087	3,864	20	1,001	500	6,528	257,316	300,000
2036	249,198	287,405	4,071	21	1,101	500	6,902	261,793	300,000
2037	252,774	286,723	4,278	22	1,201	500	7,276	266,051	300,000
2038	256,540	286,041	4,485	23	1,300	500	7,650	270,499	300,000
2039	260,184	285,359	4,693	24	1,400	500	8,024	274,825	300,000
2040	263,917	284,677	4,900	25	1,500	500	8,398	279,240	300,000
2041	267,320	284,677	4,900	25	1,500	500	8,398	282,643	300,000
2042	270,802	284,677	4,900	25	1,500	500	8,398	286,125	300,000
2043	274,263	284,677	4,900	25	1,500	500	8,398	289,586	300,000
2044	277,595	284,677	4,900	25	1,500	500	8,398	292,918	300,000
2045	280,694	284,677	4,900	25	1,500	500	8,398	296,017	300,000
2046	283,868	284,677	4,900	25	1,500	500	8,398	299,191	300,000
2047	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2048	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2049	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2050	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2051	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2052	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2053	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2054	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2055	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2056	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2057	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2058	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2059	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000
2060	284,677	284,677	4,900	25	1,500	500	8,398	300,000	300,000

NRA – National Recreation Area; P – Priority; PPR – Present Perfected Rights

[1] Southern Nevada water providers depletion schedule for alternatives with mechanism for storage and delivery of conserved water (Enhanced Coordination, Maximum Operational Flexibility, Supply Driven [Lower Basin Priority and Lower Basin Pro Rata approaches] Alternatives) and Continued Current Strategies Comparative Baseline. See **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water, for assumptions on the creation and delivery of conserved water.
[2] Southern Nevada water providers depletion schedule for the No Action and Basic Coordination Alternatives, which do not have a new mechanism for storage and delivery of conserved water.
[3] Water user has both a diversion and depletion entitlement. May include adjustments to applied efficiency.
[4] Present Perfected Right (PPR); highest priority mainstream Colorado River water entitlements that were perfected before June 25, 1929. See Section C.4.1 in Appendix C, Shortage Allocation Model and Alternative Distribution Model Documentation, for more details.
[5] Total State of Nevada water user depletion schedules for alternatives with mechanism for storage and delivery of conserved water (Enhanced Coordination, Maximum Operational Flexibility, Supply Driven [Lower Basin Priority and Lower Basin Pro Rata approaches], Preferred Alternatives) and Continued Current Strategies Comparative Baseline.
[6] Total State of Nevada water user depletion schedules for the No Action and Basic Coordination Alternatives, which do not have a new mechanism for storage and delivery of conserved water.

Table M-2a
State of California Water Users (acre-feet)

Calendar Year	Ft Mojave Indian Reservation (PPR)	City Of Needles Bernardino County (PPR)[1]	Chemehuevi Indian Reservation (PPR)	MWD Diversion (P4)[2,3]	QSA IID to MWD (P3a)	QSA CVWD to MWD (P3a)	Colorado River Indian Reservation (PPR)
2027	9,029	1,223	219	447,963	352,700	26,000	3,322
2028	9,029	1,223	673	445,125	352,700	26,000	5,602
2029	9,029	1,223	1,128	442,287	352,700	26,000	7,883
2030	9,029	1,223	1,582	439,449	352,700	26,000	10,164
2031	9,029	1,223	2,036	436,611	352,700	26,000	12,444
2032	9,029	1,223	2,490	433,774	352,700	26,000	14,725
2033	9,029	1,223	2,944	430,936	352,700	26,000	17,006
2034	9,029	1,223	3,399	428,098	352,700	26,000	19,287
2035	9,029	1,223	3,853	421,690	352,700	26,000	21,567
2036	9,029	1,223	4,307	418,852	352,700	26,000	23,848
2037	9,029	1,223	4,761	416,014	352,700	26,000	26,129
2038	9,029	1,223	5,215	413,176	352,700	26,000	28,409
2039	9,029	1,223	5,669	410,338	352,700	26,000	30,690
2040	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2041	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2042	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2043	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2044	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2045	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2046	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2047	9,029	1,223	6,124	407,501	352,700	26,000	32,971
2048	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2049	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2050	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2051	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2052	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2053	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2054	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2055	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2056	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2057	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2058	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2059	9,029	1,223	6,124	360,501	352,700	26,000	32,971
2060	9,029	1,223	6,124	360,501	352,700	26,000	32,971

CVWD – Coachella Valley Water District; MWD – Metropolitan Water District of Southern California; P – Priority; PPR – Present Perfected Rights; QSA – Quantification Settlement Agreement

[1] Water user has both a diversion and depletion entitlement. May include adjustments to applied efficiency.

[2] Adjusted to reflect operational agreements and/or input received from the water user.
[3] In response to comments received on MWD's P4 demands used in the Draft EIS, the values presented in this table reflect updated demands and better match the demand used in the Shortage Allocation Model (**Appendix C** – Shortage Allocation Model and Alternative Distribution Model Documentation). To fully incorporate the updated demands into the Final EIS analyses, all alternatives and resource models would have had to be re-run, which was not feasible within the given timeline. As such, all modeling and analyses included in this Final EIS still use the demands from the Draft EIS. A sensitivity analysis found that, while the updated demands result in minor changes, they would not significantly affect the relative ranking of alternatives or the conclusions for any resource.

Table M-2b
State of California Water Users (acre-feet)

Calendar Year	PVID (PPR)	PVID (P1)	PVID (P3b)[1]	IID (PPR)	IID (P3a)[1]	CVWD (P3a)[1]	QSA IID to CVWD (P3a)[1]
2027	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2028	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2029	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2030	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2031	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2032	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2033	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2034	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2035	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2036	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2037	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2038	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2039	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2040	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2041	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2042	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2043	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2044	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2045	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2046	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2047	94,505	368,378	5,000	2,600,000	12,800	321,000	103,000
2048	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2049	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2050	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2051	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2052	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2053	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2054	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2055	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2056	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2057	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2058	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2059	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000
2060	94,505	368,378	5,000	2,600,000	62,800	321,000	100,000

CVWD – Coachella Valley Water District; IID – Imperial Irrigation District; MWD – Metropolitan Water District of Southern California; P – Priority; PPR – Present Perfected Rights; QSA – Quantification Settlement Agreement

[1] Adjusted to reflect operational agreements and/or input received from the water user.

Table M-2c
State of California Water Users (acre-feet)

Calendar Year	Others And Misc PPR (PPR)	AAC Yuma Proj Bard Unit (PPR)	AAC Yuma Proj Res. Unit/Fort Yuma Indian Res. (PPR)[1]	AAC Yuma Proj Bard Unit (P2) [1]	Total State of California
2027	95	19,518	32,954	2,294	4,400,000
2028	198	19,518	32,954	2,294	4,400,000
2029	301	19,518	32,954	2,294	4,400,000
2030	404	19,518	32,954	2,294	4,400,000
2031	507	19,518	32,954	2,294	4,400,000
2032	610	19,518	32,954	2,294	4,400,000
2033	713	19,518	32,954	2,294	4,400,000
2034	816	19,518	32,954	2,294	4,400,000
2035	919	19,518	36,524	2,294	4,400,000
2036	1,022	19,518	36,524	2,294	4,400,000
2037	1,125	19,518	36,524	2,294	4,400,000
2038	1,228	19,518	36,524	2,294	4,400,000
2039	1,331	19,518	36,524	2,294	4,400,000
2040	1,434	19,518	36,524	2,294	4,400,000
2041	1,434	19,518	36,524	2,294	4,400,000
2042	1,434	19,518	36,524	2,294	4,400,000
2043	1,434	19,518	36,524	2,294	4,400,000
2044	1,434	19,518	36,524	2,294	4,400,000
2045	1,434	19,518	36,524	2,294	4,400,000
2046	1,434	19,518	36,524	2,294	4,400,000
2047	1,434	19,518	36,524	2,294	4,400,000
2048	1,434	19,518	36,524	2,294	4,400,000
2049	1,434	19,518	36,524	2,294	4,400,000
2050	1,434	19,518	36,524	2,294	4,400,000
2051	1,434	19,518	36,524	2,294	4,400,000
2052	1,434	19,518	36,524	2,294	4,400,000
2053	1,434	19,518	36,524	2,294	4,400,000
2054	1,434	19,518	36,524	2,294	4,400,000
2055	1,434	19,518	36,524	2,294	4,400,000
2056	1,434	19,518	36,524	2,294	4,400,000
2057	1,434	19,518	36,524	2,294	4,400,000
2058	1,434	19,518	36,524	2,294	4,400,000
2059	1,434	19,518	36,524	2,294	4,400,000
2060	1,434	19,518	36,524	2,294	4,400,000

AAC – All-American Canal; P – Priority; PPR – Present Perfected Rights

[1] Adjusted to reflect operational agreements and/or input received from the water user.

Table M-3a
State of Arizona Priority 1 Water Users (acre-feet)

Calendar Year	Ft Mojave Indian Reservation	Mohave Valley IDD	Parker[2]	EPCOR[1]	Colorado River Indian Reservation
2027	39,174	3,208	265	143	337,116
2028	40,461	3,208	265	150	337,680
2029	41,748	3,208	265	158	338,244
2030	43,036	3,208	265	165	338,808
2031	44,323	3,208	265	172	339,372
2032	45,610	3,208	265	180	339,936
2033	46,898	3,208	265	187	340,500
2034	48,185	3,208	265	194	341,065
2035	49,472	3,208	265	201	341,629
2036	50,760	3,208	265	209	342,193
2037	52,047	3,208	265	216	342,757
2038	53,334	3,208	265	223	343,321
2039	54,622	3,208	265	230	343,885
2040	55,909	3,208	265	238	344,449
2041	55,909	3,208	265	238	344,449
2042	55,909	3,208	265	238	344,449
2043	55,909	3,208	265	238	344,449
2044	55,909	3,208	265	238	344,449
2045	55,909	3,208	265	238	344,449
2046	55,909	3,208	265	238	344,449
2047	55,909	3,208	265	238	344,449
2048	55,909	3,208	265	238	344,449
2049	55,909	3,208	265	238	344,449
2050	55,909	3,208	265	238	344,449
2051	55,909	3,208	265	238	344,449
2052	55,909	3,208	265	238	344,449
2053	55,909	3,208	265	238	344,449
2054	55,909	3,208	265	238	344,449
2055	55,909	3,208	265	238	344,449
2056	55,909	3,208	265	238	344,449
2057	55,909	3,208	265	238	344,449
2058	55,909	3,208	265	238	344,449
2059	55,909	3,208	265	238	344,449
2060	55,909	3,208	265	238	344,449

IDD – Irrigation and Drainage District

[1] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

[2] Water user has both a diversion and depletion entitlement. May include adjustments to applied efficiency.

Table M-3b
State of Arizona Priority 1 Water Users (acre-feet)

Calendar Year	North Gila Valley IDD	Yuma County WUA	City Of Yuma	Unit BIDD	Cocopah Indian Res
2027	6,125	170,314	1,353	4,352	5,910
2028	6,125	170,314	1,363	4,352	5,910
2029	6,125	170,314	1,372	4,352	5,910
2030	6,125	170,314	1,382	4,352	5,910
2031	6,125	170,314	1,391	4,352	5,910
2032	6,125	170,314	1,401	4,352	5,910
2033	6,125	170,314	1,411	4,352	5,910
2034	6,125	170,314	1,420	4,352	5,910
2035	6,125	170,314	1,430	4,352	5,910
2036	6,125	170,314	1,440	4,352	5,910
2037	6,125	170,314	1,449	4,352	5,910
2038	6,125	170,314	1,459	4,352	5,910
2039	6,125	170,314	1,468	4,352	5,910
2040	6,125	170,314	1,478	4,352	5,910
2041	6,125	170,314	1,478	4,352	5,910
2042	6,125	170,314	1,478	4,352	5,910
2043	6,125	170,314	1,478	4,352	5,910
2044	6,125	170,314	1,478	4,352	5,910
2045	6,125	170,314	1,478	4,352	5,910
2046	6,125	170,314	1,478	4,352	5,910
2047	6,125	170,314	1,478	4,352	5,910
2048	6,125	170,314	1,478	4,352	5,910
2049	6,125	170,314	1,478	4,352	5,910
2050	6,125	170,314	1,478	4,352	5,910
2051	6,125	170,314	1,478	4,352	5,910
2052	6,125	170,314	1,478	4,352	5,910
2053	6,125	170,314	1,478	4,352	5,910
2054	6,125	170,314	1,478	4,352	5,910
2055	6,125	170,314	1,478	4,352	5,910
2056	6,125	170,314	1,478	4,352	5,910
2057	6,125	170,314	1,478	4,352	5,910
2058	6,125	170,314	1,478	4,352	5,910
2059	6,125	170,314	1,478	4,352	5,910
2060	6,125	170,314	1,478	4,352	5,910

BIDD – Buckeye Irrigation and Drainage District; IDD – Irrigation and Drainage District; WUA – Water Users Association

Table M-3c
State of Arizona Priority 1 Water Users (acre-feet)

Calendar Year	Gila Monster Farms	Powers	Molina	Phillips Milton And Jean[2]	Fort Yuma Indian Reservation[1]	Total State of Arizona Priority 1
2027	445	484	0	0	1,501	570,388
2028	445	494	24	3	2,334	573,128
2029	445	505	49	6	3,167	575,868
2030	445	516	73	10	4,001	578,608
2031	445	527	98	13	4,001	580,515
2032	445	538	122	16	4,001	582,422
2033	445	548	147	19	4,001	584,329
2034	445	559	171	23	4,001	586,235
2035	445	570	196	26	4,001	588,142
2036	445	581	220	29	4,001	590,049
2037	445	592	245	32	4,001	591,956
2038	445	602	269	36	4,001	593,862
2039	445	613	294	39	4,001	595,769
2040	445	624	318	42	4,001	597,676
2041	445	624	318	42	4,001	597,676
2042	445	624	318	42	4,001	597,676
2043	445	624	318	42	4,001	597,676
2044	445	624	318	42	4,001	597,676
2045	445	624	318	42	4,001	597,676
2046	445	624	318	42	4,001	597,676
2047	445	624	318	42	4,001	597,676
2048	445	624	318	42	4,001	597,676
2049	445	624	318	42	4,001	597,676
2050	445	624	318	42	4,001	597,676
2051	445	624	318	42	4,001	597,676
2052	445	624	318	42	4,001	597,676
2053	445	624	318	42	4,001	597,676
2054	445	624	318	42	4,001	597,676
2055	445	624	318	42	4,001	597,676
2056	445	624	318	42	4,001	597,676
2057	445	624	318	42	4,001	597,676
2058	445	624	318	42	4,001	597,676
2059	445	624	318	42	4,001	597,676
2060	445	624	318	42	4,001	597,676

[1] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

[2] Adjusted to reflect operational agreements and/or input received from the water user.

Table M-4
State of Arizona Priority 2 Water Users (acre-feet)

Calendar Year	Lake Mead Mohave NRA[1]	Havasu NWR[2]	Davis Dam Project	Imperial NWR[2]	Cibola NWR[2]	Total State of Arizona Priority 2
2027	343	4,594	7	2,699	10,945	18,588
2028	343	4,627	7	3,827	11,391	20,194
2029	343	4,660	7	4,954	11,836	21,801
2030	343	4,693	7	6,082	12,282	23,407
2031	343	4,725	7	7,210	12,728	25,013
2032	343	4,758	7	8,338	13,174	26,620
2033	343	4,791	7	9,466	13,620	28,226
2034	343	4,824	7	10,593	14,065	29,832
2035	343	4,857	7	11,721	14,511	31,439
2036	343	4,889	7	12,849	14,957	33,045
2037	343	4,922	7	13,977	15,403	34,652
2038	343	4,955	7	15,104	15,848	36,258
2039	343	4,988	7	16,232	16,294	37,864
2040	343	5,021	7	17,360	16,740	39,471
2041	343	5,021	7	17,360	16,740	39,471
2042	343	5,021	7	17,360	16,740	39,471
2043	343	5,021	7	17,360	16,740	39,471
2044	343	5,021	7	17,360	16,740	39,471
2045	343	5,021	7	17,360	16,740	39,471
2046	343	5,021	7	17,360	16,740	39,471
2047	343	5,021	7	17,360	16,740	39,471
2048	343	5,021	7	17,360	16,740	39,471
2049	343	5,021	7	17,360	16,740	39,471
2050	343	5,021	7	17,360	16,740	39,471
2051	343	5,021	7	17,360	16,740	39,471
2052	343	5,021	7	17,360	16,740	39,471
2053	343	5,021	7	17,360	16,740	39,471
2054	343	5,021	7	17,360	16,740	39,471
2055	343	5,021	7	17,360	16,740	39,471
2056	343	5,021	7	17,360	16,740	39,471
2057	343	5,021	7	17,360	16,740	39,471
2058	343	5,021	7	17,360	16,740	39,471
2059	343	5,021	7	17,360	16,740	39,471
2060	343	5,021	7	17,360	16,740	39,471

NRA – National Recreation Area; NWR – National Wildlife Refuge

[1] Unquantified entitlement, estimated using the three-year average of historical maximum use.

[2] Water user has both a diversion and depletion entitlement. May include adjustments to applied efficiency.

Table M-5a
State of Arizona Priority 3 Water Users (acre-feet)

Calendar Year	Ak-Chin Indian Community	Salt River Pima-Maricopa Indian Community[1]	Army Yuma Proving Ground	Navy Marine Corps Yuma Air Station	Univ Of Arizona	Yuma Mesa Fruit Growers Assn
2027	50,000	22,000	710	1,548	943	0
2028	50,000	22,000	742	1,660	954	1
2029	50,000	22,000	774	1,771	965	2
2030	50,000	22,000	807	1,883	976	3
2031	50,000	22,000	839	1,995	988	5
2032	50,000	22,000	871	2,106	999	6
2033	50,000	22,000	903	2,218	1,010	7
2034	50,000	22,000	936	2,330	1,021	8
2035	50,000	22,000	968	2,442	1,032	9
2036	50,000	22,000	1,000	2,553	1,043	10
2037	50,000	22,000	1,032	2,665	1,055	12
2038	50,000	22,000	1,065	2,777	1,066	13
2039	50,000	22,000	1,097	2,888	1,077	14
2040	50,000	22,000	1,129	3,000	1,088	15
2041	50,000	22,000	1,129	3,000	1,088	15
2042	50,000	22,000	1,129	3,000	1,088	15
2043	50,000	22,000	1,129	3,000	1,088	15
2044	50,000	22,000	1,129	3,000	1,088	15
2045	50,000	22,000	1,129	3,000	1,088	15
2046	50,000	22,000	1,129	3,000	1,088	15
2047	50,000	22,000	1,129	3,000	1,088	15
2048	50,000	22,000	1,129	3,000	1,088	15
2049	50,000	22,000	1,129	3,000	1,088	15
2050	50,000	22,000	1,129	3,000	1,088	15
2051	50,000	22,000	1,129	3,000	1,088	15
2052	50,000	22,000	1,129	3,000	1,088	15
2053	50,000	22,000	1,129	3,000	1,088	15
2054	50,000	22,000	1,129	3,000	1,088	15
2055	50,000	22,000	1,129	3,000	1,088	15
2056	50,000	22,000	1,129	3,000	1,088	15
2057	50,000	22,000	1,129	3,000	1,088	15
2058	50,000	22,000	1,129	3,000	1,088	15
2059	50,000	22,000	1,129	3,000	1,088	15
2060	50,000	22,000	1,129	3,000	1,088	15

[1] See Public Law 100-512, 102 Stat. 2549 (Oct. 20, 1988)

Table M-5b
State of Arizona Priority 3 Water Users (acre-feet)

Calendar Year	Yuma Union High School	Yuma Cemetery	City Of Yuma[1]	Yuma Irrigation Dist	Unit B IDD	Yuma Mesa IDD
2027	148	0	14,915	39,165	16,886	141,519
2028	148	5	17,500	41,328	16,886	141,519
2029	148	9	20,085	43,490	16,886	141,519
2030	148	14	22,670	45,653	16,886	141,519
2031	148	18	25,256	47,815	16,886	141,519
2032	148	23	27,841	49,978	16,886	141,519
2033	148	28	30,426	52,140	16,886	141,519
2034	148	32	33,011	54,303	16,886	141,519
2035	148	37	35,596	56,465	16,886	141,519
2036	148	42	38,181	58,628	16,886	141,519
2037	148	46	40,767	60,790	16,886	141,519
2038	148	51	43,352	62,953	16,886	141,519
2039	148	55	45,937	65,115	16,886	141,519
2040	148	60	48,522	67,278	16,886	141,519
2041	148	60	48,522	67,278	16,886	141,519
2042	148	60	48,522	67,278	16,886	141,519
2043	148	60	48,522	67,278	16,886	141,519
2044	148	60	48,522	67,278	16,886	141,519
2045	148	60	48,522	67,278	16,886	141,519
2046	148	60	48,522	67,278	16,886	141,519
2047	148	60	48,522	67,278	16,886	141,519
2048	148	60	48,522	67,278	16,886	141,519
2049	148	60	48,522	67,278	16,886	141,519
2050	148	60	48,522	67,278	16,886	141,519
2051	148	60	48,522	67,278	16,886	141,519
2052	148	60	48,522	67,278	16,886	141,519
2053	148	60	48,522	67,278	16,886	141,519
2054	148	60	48,522	67,278	16,886	141,519
2055	148	60	48,522	67,278	16,886	141,519
2056	148	60	48,522	67,278	16,886	141,519
2057	148	60	48,522	67,278	16,886	141,519
2058	148	60	48,522	67,278	16,886	141,519
2059	148	60	48,522	67,278	16,886	141,519
2060	148	60	48,522	67,278	16,886	141,519

IDD – Irrigation and Drainage District

[1] Water user has both a diversion and depletion entitlement. May include adjustments to applied efficiency.

Table M-5c
State of Arizona Priority 3 Water Users (acre-feet)

Calendar Year	Wellton Mohawk IDD	Kaman Inc	North Gila Valley IDD	Yuma County WUA	Gila Monster Farms	Desert Lawn Memorial Park[1]
2027	262,125	0	6,731	79,304	3,582	34
2028	263,346	0	6,731	79,304	3,582	42
2029	264,567	0	6,731	79,304	3,582	50
2030	265,788	0	6,731	79,304	3,582	58
2031	267,010	1	6,731	79,304	3,582	66
2032	268,231	1	6,731	79,304	3,582	74
2033	269,452	1	6,731	79,304	3,582	82
2034	270,673	1	6,731	79,304	3,582	90
2035	271,894	1	6,731	79,304	3,582	98
2036	273,115	1	6,731	79,304	3,582	106
2037	274,337	2	6,731	79,304	3,582	114
2038	275,558	2	6,731	79,304	3,582	122
2039	276,779	2	6,731	79,304	3,582	130
2040	278,000	2	6,731	79,304	3,582	138
2041	278,000	2	6,731	79,304	3,582	138
2042	278,000	2	6,731	79,304	3,582	138
2043	278,000	2	6,731	79,304	3,582	138
2044	278,000	2	6,731	79,304	3,582	138
2045	278,000	2	6,731	79,304	3,582	138
2046	278,000	2	6,731	79,304	3,582	138
2047	278,000	2	6,731	79,304	3,582	138
2048	278,000	2	6,731	79,304	3,582	138
2049	278,000	2	6,731	79,304	3,582	138
2050	278,000	2	6,731	79,304	3,582	138
2051	278,000	2	6,731	79,304	3,582	138
2052	278,000	2	6,731	79,304	3,582	138
2053	278,000	2	6,731	79,304	3,582	138
2054	278,000	2	6,731	79,304	3,582	138
2055	278,000	2	6,731	79,304	3,582	138
2056	278,000	2	6,731	79,304	3,582	138
2057	278,000	2	6,731	79,304	3,582	138
2058	278,000	2	6,731	79,304	3,582	138
2059	278,000	2	6,731	79,304	3,582	138
2060	278,000	2	6,731	79,304	3,582	138

IDD – Irrigation and Drainage District; WUA – Water Users Association

[1] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

Table M-5d
State of Arizona Priority 3 Water Users (acre-feet)

Calendar Year	Alec Camille	Union Pacific Co	Harold Sturges	Irma Sturges	Total State of Arizona Priority 3
2027	0	25	0	0	639,636
2028	9	25	26	30	645,838
2029	18	25	52	59	652,040
2030	28	25	77	89	658,243
2031	37	25	103	118	664,445
2032	46	25	129	148	670,648
2033	55	25	155	178	676,850
2034	65	25	180	207	683,053
2035	74	25	206	237	689,255
2036	83	25	232	267	695,458
2037	92	25	258	296	701,660
2038	102	25	283	326	707,863
2039	111	25	309	355	714,065
2040	120	25	335	385	720,268
2041	120	25	335	385	720,268
2042	120	25	335	385	720,268
2043	120	25	335	385	720,268
2044	120	25	335	385	720,268
2045	120	25	335	385	720,268
2046	120	25	335	385	720,268
2047	120	25	335	385	720,268
2048	120	25	335	385	720,268
2049	120	25	335	385	720,268
2050	120	25	335	385	720,268
2051	120	25	335	385	720,268
2052	120	25	335	385	720,268
2053	120	25	335	385	720,268
2054	120	25	335	385	720,268
2055	120	25	335	385	720,268
2056	120	25	335	385	720,268
2057	120	25	335	385	720,268
2058	120	25	335	385	720,268
2059	120	25	335	385	720,268
2060	120	25	335	385	720,268

Table M-6a
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	TV Marble Canyon AZ	McAlister Family Trust	Mohave Valley IDD Ag Portion	Mohave Valley IDD M&I Portion	Mohave Co WA Subcontract	Mohave County WA	Mohave Water Cons Dist
2027	10	7	12,827	2,700	675	0	761
2028	13	8	13,089	2,700	675	0	795
2029	15	10	13,351	2,700	675	0	830
2030	18	12	13,613	2,700	675	0	864
2031	21	13	13,875	2,700	675	0	898
2032	24	15	14,137	2,700	675	0	932
2033	26	16	14,399	2,700	675	0	966
2034	29	18	14,661	2,700	675	0	1,001
2035	32	20	14,922	2,700	675	0	1,035
2036	35	21	15,184	2,700	675	0	1,069
2037	37	23	15,446	2,700	675	0	1,103
2038	40	24	15,708	2,700	675	0	1,138
2039	43	26	15,970	2,700	675	0	1,172
2040	46	28	16,232	2,700	675	0	1,206
2041	46	28	16,232	2,700	675	0	1,206
2042	46	28	16,232	2,700	675	0	1,206
2043	46	28	16,232	2,700	675	0	1,206
2044	46	28	16,232	2,700	675	0	1,206
2045	46	28	16,232	2,700	675	0	1,206
2046	46	28	16,232	2,700	675	0	1,206
2047	46	28	16,232	2,700	675	0	1,206
2048	46	28	16,232	2,700	675	0	1,206
2049	46	28	16,232	2,700	675	0	1,206
2050	46	28	16,232	2,700	675	0	1,206
2051	46	28	16,232	2,700	675	0	1,206
2052	46	28	16,232	2,700	675	0	1,206
2053	46	28	16,232	2,700	675	0	1,206
2054	46	28	16,232	2,700	675	0	1,206
2055	46	28	16,232	2,700	675	0	1,206
2056	46	28	16,232	2,700	675	0	1,206
2057	46	28	16,232	2,700	675	0	1,206
2058	46	28	16,232	2,700	675	0	1,206
2059	46	28	16,232	2,700	675	0	1,206
2060	46	28	16,232	2,700	675	0	1,206

AZ – Arizona; IDD – Irrigation and Drainage District; M&I – municipal and industrial; WA – Water Authority

Table M-6b
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	AZ State Land Dept M&I	AZ State Parks Windsor Beach	Bullhead City	Bureau Land Mgmt	Crystal Beach WCD	Golden Shores WCD	Lake Havasu City
2027	63	12	7,443	1,193	73	319	9,441
2028	133	16	7,643	1,410	74	397	9,630
2029	204	19	7,843	1,626	75	476	9,819
2030	275	23	8,042	1,843	76	555	10,008
2031	346	27	8,242	2,060	77	633	10,197
2032	416	30	8,442	2,276	78	712	10,386
2033	487	34	8,641	2,493	79	790	10,576
2034	558	37	8,841	2,710	80	869	10,765
2035	628	41	9,040	2,927	81	947	10,954
2036	699	44	9,240	3,143	82	1,026	11,143
2037	770	48	9,440	3,360	83	1,104	11,332
2038	840	51	9,639	3,577	84	1,183	11,521
2039	911	55	9,839	3,793	85	1,261	11,711
2040	982	59	10,039	4,010	86	1,340	11,900
2041	982	59	10,039	4,010	86	1,340	11,900
2042	982	59	10,039	4,010	86	1,340	11,900
2043	982	59	10,039	4,010	86	1,340	11,900
2044	982	59	10,039	4,010	86	1,340	11,900
2045	982	59	10,039	4,010	86	1,340	11,900
2046	982	59	10,039	4,010	86	1,340	11,900
2047	982	59	10,039	4,010	86	1,340	11,900
2048	982	59	10,039	4,010	86	1,340	11,900
2049	982	59	10,039	4,010	86	1,340	11,900
2050	982	59	10,039	4,010	86	1,340	11,900
2051	982	59	10,039	4,010	86	1,340	11,900
2052	982	59	10,039	4,010	86	1,340	11,900
2053	982	59	10,039	4,010	86	1,340	11,900
2054	982	59	10,039	4,010	86	1,340	11,900
2055	982	59	10,039	4,010	86	1,340	11,900
2056	982	59	10,039	4,010	86	1,340	11,900
2057	982	59	10,039	4,010	86	1,340	11,900
2058	982	59	10,039	4,010	86	1,340	11,900
2059	982	59	10,039	4,010	86	1,340	11,900
2060	982	59	10,039	4,010	86	1,340	11,900

AZ – Arizona; M&I – municipal and industrial; WCD – Water Conservation District

Table M-6c
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	Unallocated Priority 4	Springs Del Sol	Gold Dome Mining Co	Mohave Water Cons Dist Mohave Co WA Subcontract	Bullhead City Mohave Co WA Subcontract	Lake Havasu City Mohave Co WA Subcontract	CAP
2027	0	3	0	0	0	0	1,511,829
2028	759	8	1	155	464	448	1,497,549
2029	1,518	14	1	309	928	896	1,483,270
2030	2,278	19	2	464	1,392	1,343	1,468,991
2031	3,037	24	2	618	1,856	1,791	1,455,545
2032	3,796	30	3	773	2,320	2,239	1,442,099
2033	4,555	35	3	928	2,784	2,687	1,428,653
2034	5,315	41	4	1,082	3,248	3,134	1,415,207
2035	6,074	46	4	1,237	3,712	3,582	1,401,761
2036	6,833	51	5	1,392	4,176	4,030	1,388,315
2037	7,592	57	5	1,546	4,640	4,478	1,374,869
2038	8,352	62	6	1,701	5,104	4,926	1,361,423
2039	9,111	68	6	1,855	5,568	5,373	1,347,977
2040	9,870	73	7	2,010	6,032	5,821	1,334,531
2041	9,870	73	7	2,010	6,032	5,821	1,334,531
2042	9,870	73	7	2,010	6,032	5,821	1,334,531
2043	9,870	73	7	2,010	6,032	5,821	1,334,531
2044	9,870	73	7	2,010	6,032	5,821	1,334,531
2045	9,870	73	7	2,010	6,032	5,821	1,334,531
2046	9,870	73	7	2,010	6,032	5,821	1,334,531
2047	9,870	73	7	2,010	6,032	5,821	1,334,531
2048	9,870	73	7	2,010	6,032	5,821	1,334,531
2049	9,870	73	7	2,010	6,032	5,821	1,334,531
2050	9,870	73	7	2,010	6,032	5,821	1,334,531
2051	9,870	73	7	2,010	6,032	5,821	1,334,531
2052	9,870	73	7	2,010	6,032	5,821	1,334,531
2053	9,870	73	7	2,010	6,032	5,821	1,334,531
2054	9,870	73	7	2,010	6,032	5,821	1,334,531
2055	9,870	73	7	2,010	6,032	5,821	1,334,531
2056	9,870	73	7	2,010	6,032	5,821	1,334,531
2057	9,870	73	7	2,010	6,032	5,821	1,334,531
2058	9,870	73	7	2,010	6,032	5,821	1,334,531
2059	9,870	73	7	2,010	6,032	5,821	1,334,531
2060	9,870	73	7	2,010	6,032	5,821	1,334,531

CAP – Central Arizona Project; WA – Water Authority

Table M-6d
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	Indian Water Rights Settlements Priority 4[1]	North Baja LLC	Matador	EPCOR[2]	Ehrenberg Impr Dist	Hillcrest Water Co	Parker
2027	0	209	2,912	745	273	23	91
2028	269	217	2,913	783	288	25	117
2029	538	225	2,914	821	303	28	143
2030	808	233	2,915	859	317	30	170
2031	1,077	240	2,916	896	332	33	196
2032	1,346	248	2,917	934	346	35	222
2033	1,615	256	2,918	972	361	37	249
2034	1,885	264	2,919	1,010	376	40	275
2035	2,154	272	2,920	1,048	390	42	301
2036	2,423	280	2,921	1,086	405	45	327
2037	2,692	288	2,922	1,123	419	47	354
2038	2,962	296	2,923	1,161	434	50	380
2039	3,231	304	2,924	1,199	448	52	406
2040	3,500	312	2,925	1,237	463	55	433
2041	3,500	312	2,925	1,237	463	55	433
2042	3,500	312	2,925	1,237	463	55	433
2043	3,500	312	2,925	1,237	463	55	433
2044	3,500	312	2,925	1,237	463	55	433
2045	3,500	312	2,925	1,237	463	55	433
2046	3,500	312	2,925	1,237	463	55	433
2047	3,500	312	2,925	1,237	463	55	433
2048	3,500	312	2,925	1,237	463	55	433
2049	3,500	312	2,925	1,237	463	55	433
2050	3,500	312	2,925	1,237	463	55	433
2051	3,500	312	2,925	1,237	463	55	433
2052	3,500	312	2,925	1,237	463	55	433
2053	3,500	312	2,925	1,237	463	55	433
2054	3,500	312	2,925	1,237	463	55	433
2055	3,500	312	2,925	1,237	463	55	433
2056	3,500	312	2,925	1,237	463	55	433
2057	3,500	312	2,925	1,237	463	55	433
2058	3,500	312	2,925	1,237	463	55	433
2059	3,500	312	2,925	1,237	463	55	433
2060	3,500	312	2,925	1,237	463	55	433

[1] See paragraph 11.3 of the Arizona Water Settlement Agreement, which is also referred to as the "master agreement" in the Arizona Water Settlements Act, Pub. L. 108-451 (Dec. 10. 2004).

[2] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

Table M-6e
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	Quartzsite	Frontier Comm West Coast	BF Investments	La Paz County	Hopi Tribe[1]	Cibola Valley IDD	AZ Game and Fish Com
2027	0	1	8	0	3,037	5,285	2,043
2028	82	1	10	27	3,133	5,285	2,043
2029	165	1	13	54	3,228	5,285	2,043
2030	247	1	15	81	3,324	5,285	2,043
2031	329	1	18	108	3,419	5,285	2,043
2032	412	1	21	135	3,515	5,285	2,043
2033	494	1	23	162	3,610	5,285	2,043
2034	576	1	26	188	3,705	5,285	2,043
2035	658	1	28	215	3,801	5,285	2,043
2036	741	1	31	242	3,896	5,285	2,043
2037	823	1	34	269	3,992	5,285	2,043
2038	905	1	36	296	4,087	5,285	2,043
2039	988	1	39	323	4,183	5,285	2,043
2040	1,070	1	41	350	4,278	5,285	2,043
2041	1,070	1	41	350	4,278	5,285	2,043
2042	1,070	1	41	350	4,278	5,285	2,043
2043	1,070	1	41	350	4,278	5,285	2,043
2044	1,070	1	41	350	4,278	5,285	2,043
2045	1,070	1	41	350	4,278	5,285	2,043
2046	1,070	1	41	350	4,278	5,285	2,043
2047	1,070	1	41	350	4,278	5,285	2,043
2048	1,070	1	41	350	4,278	5,285	2,043
2049	1,070	1	41	350	4,278	5,285	2,043
2050	1,070	1	41	350	4,278	5,285	2,043
2051	1,070	1	41	350	4,278	5,285	2,043
2052	1,070	1	41	350	4,278	5,285	2,043
2053	1,070	1	41	350	4,278	5,285	2,043
2054	1,070	1	41	350	4,278	5,285	2,043
2055	1,070	1	41	350	4,278	5,285	2,043
2056	1,070	1	41	350	4,278	5,285	2,043
2057	1,070	1	41	350	4,278	5,285	2,043
2058	1,070	1	41	350	4,278	5,285	2,043
2059	1,070	1	41	350	4,278	5,285	2,043
2060	1,070	1	41	350	4,278	5,285	2,043

AZ – Arizona; IDD – Irrigation and Drainage District

[1] Adjusted to reflect operational agreements and/or input received from the water user.

Table M-6f
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	GSC Farm	Red River Land Co	Western Water	Bishop Family Trust	Cathcarts	Cibola Sportsman's Club	Gila Monster Farms
2027	50	210	63	196	22	146	583
2028	50	210	88	204	27	147	601
2029	50	211	112	212	32	147	619
2030	50	211	137	220	38	148	637
2031	50	211	162	227	43	148	655
2032	50	211	187	235	48	149	673
2033	50	211	212	243	53	150	691
2034	50	212	237	251	58	150	710
2035	50	212	262	259	64	151	728
2036	50	212	286	267	69	151	746
2037	50	212	311	275	74	152	764
2038	50	213	336	282	79	152	782
2039	50	213	361	290	84	153	800
2040	50	213	386	298	89	153	818
2041	50	213	386	298	89	153	818
2042	50	213	386	298	89	153	818
2043	50	213	386	298	89	153	818
2044	50	213	386	298	89	153	818
2045	50	213	386	298	89	153	818
2046	50	213	386	298	89	153	818
2047	50	213	386	298	89	153	818
2048	50	213	386	298	89	153	818
2049	50	213	386	298	89	153	818
2050	50	213	386	298	89	153	818
2051	50	213	386	298	89	153	818
2052	50	213	386	298	89	153	818
2053	50	213	386	298	89	153	818
2054	50	213	386	298	89	153	818
2055	50	213	386	298	89	153	818
2056	50	213	386	298	89	153	818
2057	50	213	386	298	89	153	818
2058	50	213	386	298	89	153	818
2059	50	213	386	298	89	153	818
2060	50	213	386	298	89	153	818

Table M-6g
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	Desert Lawn Memorial Park[1]	Cocopah Indian Res	Fisher Landing	Shepard Water Co	Martinez Lake Sites	Curtis Armon	Perricone Meyer Farms
2027	61	31	10	22	7	137	1,223
2028	75	133	12	23	8	141	1,234
2029	90	235	14	24	8	146	1,245
2030	104	337	16	25	9	150	1,256
2031	118	439	18	25	9	155	1,267
2032	133	541	20	26	10	159	1,278
2033	147	643	22	27	11	164	1,289
2034	162	745	24	28	11	168	1,300
2035	176	847	26	29	12	173	1,311
2036	191	949	28	29	12	177	1,321
2037	205	1,051	30	30	13	182	1,332
2038	220	1,153	32	31	14	186	1,343
2039	234	1,255	34	32	14	191	1,354
2040	248	1,357	36	33	15	195	1,365
2041	248	1,357	36	33	15	195	1,365
2042	248	1,357	36	33	15	195	1,365
2043	248	1,357	36	33	15	195	1,365
2044	248	1,357	36	33	15	195	1,365
2045	248	1,357	36	33	15	195	1,365
2046	248	1,357	36	33	15	195	1,365
2047	248	1,357	36	33	15	195	1,365
2048	248	1,357	36	33	15	195	1,365
2049	248	1,357	36	33	15	195	1,365
2050	248	1,357	36	33	15	195	1,365
2051	248	1,357	36	33	15	195	1,365
2052	248	1,357	36	33	15	195	1,365
2053	248	1,357	36	33	15	195	1,365
2054	248	1,357	36	33	15	195	1,365
2055	248	1,357	36	33	15	195	1,365
2056	248	1,357	36	33	15	195	1,365
2057	248	1,357	36	33	15	195	1,365
2058	248	1,357	36	33	15	195	1,365
2059	248	1,357	36	33	15	195	1,365
2060	248	1,357	36	33	15	195	1,365

[1] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

Table M-6h
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	JRJ Partners	Ogram Boys Enterprises	Ott Family	Phillips Milton and Jean[1]	Beattie Farms Southwest	Pasquinelli Gary and Barbara	Edward Roy
2027	677	598	294	0	610	237	0
2028	679	598	296	5	619	243	0
2029	681	598	297	9	627	249	0
2030	683	599	299	14	636	255	0
2031	684	599	300	18	645	261	0
2032	686	599	301	23	653	268	0
2033	688	599	303	28	662	274	0
2034	690	599	304	32	670	280	1
2035	692	600	305	37	679	286	1
2036	694	600	307	42	687	292	1
2037	696	600	308	46	696	298	1
2038	698	600	309	51	704	304	1
2039	700	600	311	55	713	310	1
2040	702	601	312	60	722	316	1
2041	702	601	312	60	722	316	1
2042	702	601	312	60	722	316	1
2043	702	601	312	60	722	316	1
2044	702	601	312	60	722	316	1
2045	702	601	312	60	722	316	1
2046	702	601	312	60	722	316	1
2047	702	601	312	60	722	316	1
2048	702	601	312	60	722	316	1
2049	702	601	312	60	722	316	1
2050	702	601	312	60	722	316	1
2051	702	601	312	60	722	316	1
2052	702	601	312	60	722	316	1
2053	702	601	312	60	722	316	1
2054	702	601	312	60	722	316	1
2055	702	601	312	60	722	316	1
2056	702	601	312	60	722	316	1
2057	702	601	312	60	722	316	1
2058	702	601	312	60	722	316	1
2059	702	601	312	60	722	316	1
2060	702	601	312	60	722	316	1

[1] Water user has multiple priorities with distinct service areas. As a result, the average historical maximum use is allocated proportionally. This approach effectively assumes water is not historically diverted under the senior water entitlement(s) before the junior water entitlement(s).

Table M-6i
State of Arizona Priority 4 Water Users (acre-feet)

Calendar Year	Somerton	AZ State Land Dept Ag	Total State of Arizona Priority 4
2027	0	4,228	1,571,388
2028	58	4,228	1,560,840
2029	115	4,228	1,550,291
2030	173	4,228	1,539,742
2031	231	4,228	1,530,026
2032	288	4,228	1,520,311
2033	346	4,228	1,510,595
2034	404	4,228	1,500,879
2035	462	4,228	1,491,164
2036	519	4,228	1,481,448
2037	577	4,228	1,471,732
2038	635	4,228	1,462,017
2039	692	4,228	1,452,301
2040	750	4,228	1,442,586
2041	750	4,228	1,442,586
2042	750	4,228	1,442,586
2043	750	4,228	1,442,586
2044	750	4,228	1,442,586
2045	750	4,228	1,442,586
2046	750	4,228	1,442,586
2047	750	4,228	1,442,586
2048	750	4,228	1,442,586
2049	750	4,228	1,442,586
2050	750	4,228	1,442,586
2051	750	4,228	1,442,586
2052	750	4,228	1,442,586
2053	750	4,228	1,442,586
2054	750	4,228	1,442,586
2055	750	4,228	1,442,586
2056	750	4,228	1,442,586
2057	750	4,228	1,442,586
2058	750	4,228	1,442,586
2059	750	4,228	1,442,586
2060	750	4,228	1,442,586

AZ – Arizona

Appendix N

International Border Region of the Colorado River

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
ADM	Alternative Distribution Model
af	acre-feet
CCS	Continued Current Strategies
CRSS	Colorado River Simulation System
EIS	environmental impact statement
IBWC	International Boundary and Water Commission, United States and Mexico
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LDS	Lower Division States
maf	million acre-feet
maf/year	million acre-feet per year
mcm	million cubic meters
Mexico	United Mexican States
mg/L	Milligrams per liter
MODE	Main Outlet Drain Extension
NDVI	Normalized Difference Vegetation Index
NIB	Northerly International Boundary
ppm	parts per million
Reclamation	Bureau of Reclamation
SAM	Shortage Allocation Model
SIB	Southerly International Boundary
U.S.	United States
USIBWC	United States Section, International Boundary and Water Commission

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Appendix N. International Border Region of the Colorado River[1]

N.1 Introduction

The United States (U.S.) has a delivery obligation to the United Mexican States (Mexico) for waters of the Colorado River pursuant to the February 3, 1944 Water Treaty between the U.S. and Mexico Relating to the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty; U.S. and Mexico 1944). The U.S. Section of the International Boundary and Water Commission (USIBWC) is the U.S. component of a binational organization responsible for administration of the provisions of the 1944 Water Treaty, which includes the Colorado River waters allotted to Mexico. The International Boundary and Water Commission (IBWC) consists of the U.S. Section and the Mexican Section, which have their headquarters in the adjoining cities of El Paso, Texas and Ciudad Juarez, Chihuahua, respectively. Other Colorado River responsibilities identified in the 1944 Water Treaty relate to water delivery, border sanitation, and construction of the Mexican diversion dam (Morelos Dam), stream gaging stations, and flood control levees. The treaty gives the USIBWC, under the foreign policy guidance of the Department of State in the U.S. and the Ministry of Foreign Affairs in Mexico, the authority to settle all differences with respect to the interpretation or application of the treaty, subject to the approval of the two Governments.

The proposed federal action is for the purpose of adopting additional operational guidelines to improve the U.S. Bureau of Reclamation's (Reclamation) annual management and operation of key Colorado River reservoirs for an interim period. The objective of this appendix is to consolidate and summarize analyses related to the International Border Region throughout this Final Environmental Impact Statement (EIS), which are discussed in Technical Appendices titled **TA 3**, Hydrologic Resources, **TA 4**, Water Deliveries, and **TA 6**, Water Quality. Each of the referenced sections utilizes a simulation model to characterize the implications of the baselines and proposed alternatives on the parameters relevant to these resources.[2] To assess the proposed federal action in the EIS, certain modeling assumptions are used to evaluate potential effects on water deliveries to Mexico and on hydrologic and other environmental resources between the Northerly and Southerly International Boundaries (International Border Region). This geographic area is called the

[1] For purposes of this Appendix, the International Border Region is defined as the geographic area between the Northerly International Boundary and the Southerly International Boundary along the Colorado River. This area serves as the international boundary between the U.S. and Mexico.

[2] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Limitrophe as the Colorado River is the U.S./Mexico international boundary between those two locations.

N.2 Overview

N.2.1 Affected Environment

The international border region of the Colorado River extends from the Northerly International Boundary (NIB) to the Southerly International Boundary (SIB) where the river channel forms the international boundary between the U.S. (the State of Arizona) on the eastern side of the bank and Mexico (the State of Baja California) on the western side of the bank (**Map N-1**). Approximately 25 miles (40.2 kilometers) upstream of the NIB sits the Imperial Dam, where diversions are made into the Gila Gravity Main Canal and All-American Canal, the latter of which feeds into the Coachella Canal, East Highline Canal, and Central Main Canal before terminating at the western end of the Imperial Valley where it drains into the Westside Main Canal. Some deliveries to Mexico are channeled through the All-American Canal and then diverted either through the Pilot Knob Power Plant or through Siphon Drop and the Yuma Main Canal before returning to the mainstem channel above NIB. Another route is to direct water from Imperial Dam to Laguna Dam before returning to the mainstem channel. Approximately 1.08 miles (1.75 kilometers) downstream of the NIB along the main Colorado River channel is the Morelos Diversion Dam, which diverts water into the Reforma Canal for use in Mexico.

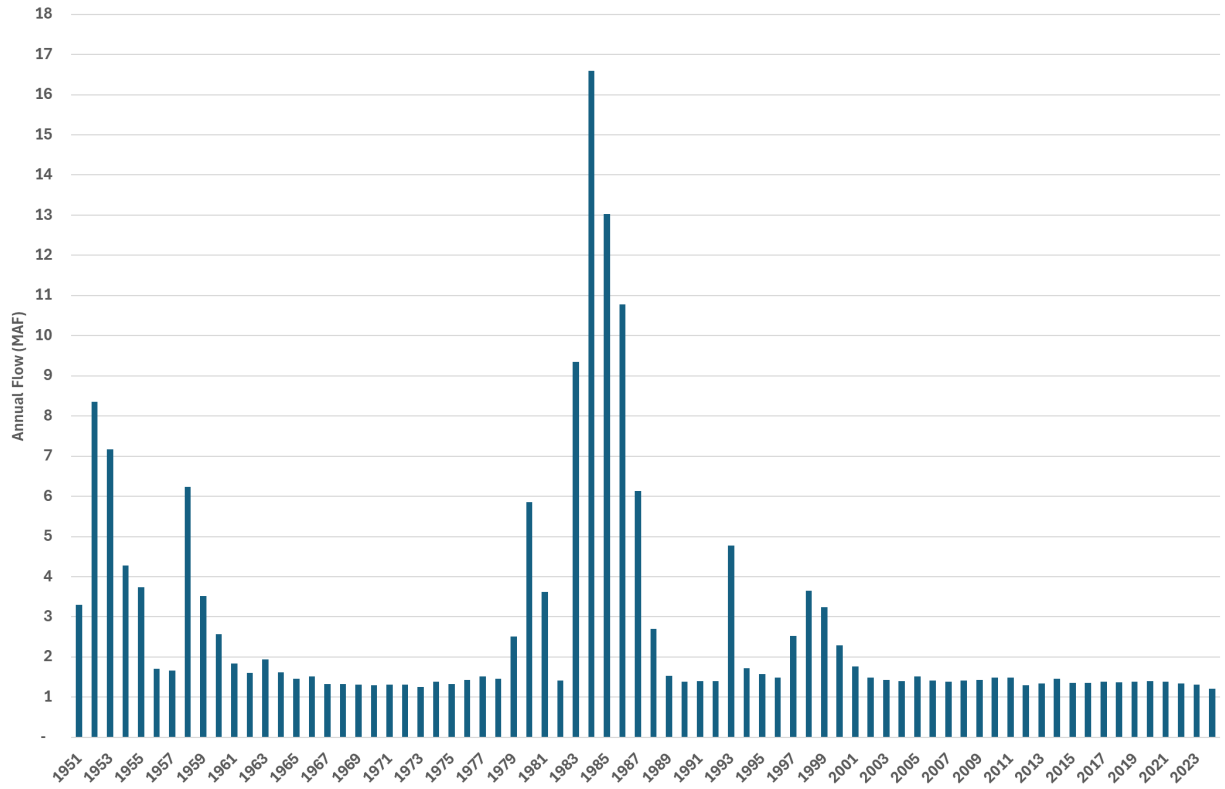
Flows at the NIB reflect releases made from Hoover Dam to meet delivery obligations to Mexico, flood control releases from Hoover Dam, local runoff sources such as irrigation return flows and pumped groundwater discharged into the river channel, unexpected flooding from the Gila River, inadvertent overruns of water deliveries that could not be diverted as intended into the Gila Gravity Main Canal or All-American Canal, and any water released for environmental purposes of the Colorado River Delta region. Under most years, the volume meets or slightly exceeds the delivery obligations to Mexico at NIB, but exceptionally large volumes have occurred in past years primarily due to flood control releases (**Figure N-1**).

The reach between the NIB and SIB is referred to as the Limitrophe. From NIB to the Morelos Dam, approximately 1.36 maf passes annually. Under normal operations, the Morelos Dam diverts the entirety of the remaining Colorado River into the Reforma Canal. Releases or spillway discharges from the Morelos Dam for flood control purposes or environmental restoration have been an infrequent but important source of downstream flows. In recent years, only seepage under and around the dam remains in the natural river channel.

Below Morelos Dam, the Colorado River is characterized by a minimally flowing or dry streambed. Seepage from the dam is joined by agricultural return flows from both the U.S. and Mexico, originating from irrigated fields percolating water into the subsurface alluvium and contributions from three U.S. wasteways (11 Mile Wasteway off levee road and County 11th, 21 Mile Wasteway near Hunters Hole, and a Diversion Channel at SIB near the border at San Luis, Arizona). The Limitrophe is typically considered to be the northernmost reach of the Colorado River Delta and


BUREAU OF RECLAMATION
Map N-1 Colorado River Infrastructure and Hydrologic Features near the U.S. and Mexico Border
Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: July 15, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.
To Lake Havasu
La Paz County
Yuma County
Lower Basin
CALIFORNIA
Imperial County
Coachella Canal
Gila Gravity Main Canal
Imperial Dam
Siphon Drop Power Plant
State boundary
Laguna Diversion
Pilot Knob Power Plant
Yuma Main Canal
All American Canal
USA
MEXICO
Morelos Diversion Dam
Gila River
Reforma Canal
ARIZONA
BAJA CALIFORNIA
Colorado River Limitrophe
State boundary
USA
MEXICO
SONORA
N
0
5
Miles
Colorado River
Major Colorado River tributary
Canal
Major dam
Hydroelectric power plant
Waterbody
Colorado River Basin, Upper and Lower Basins
States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)
WY
NV
UT
Upper Basin
CO
CA
AZ
Lower Basin
NM
MX

Figure N-1
Colorado River at Northerly International Boundary (NIB)
Above Rockwood Weir



Source: IBWC 2026, USGS 2025a

receives less than 3 inches of annual rainfall. Major flows in the Limitrophe have not regularly occurred since the 1980s and to a lesser degree in the 1990s when the reservoirs of Lake Powell Mead and Lake Mead were nearly full and spilling water was required. Notable events occurred from the 1993 Gila River floods and a pilot project that introduced environmental restoration flows (i.e. a "pulse flow") in 2014 under Minute 319 as described below.

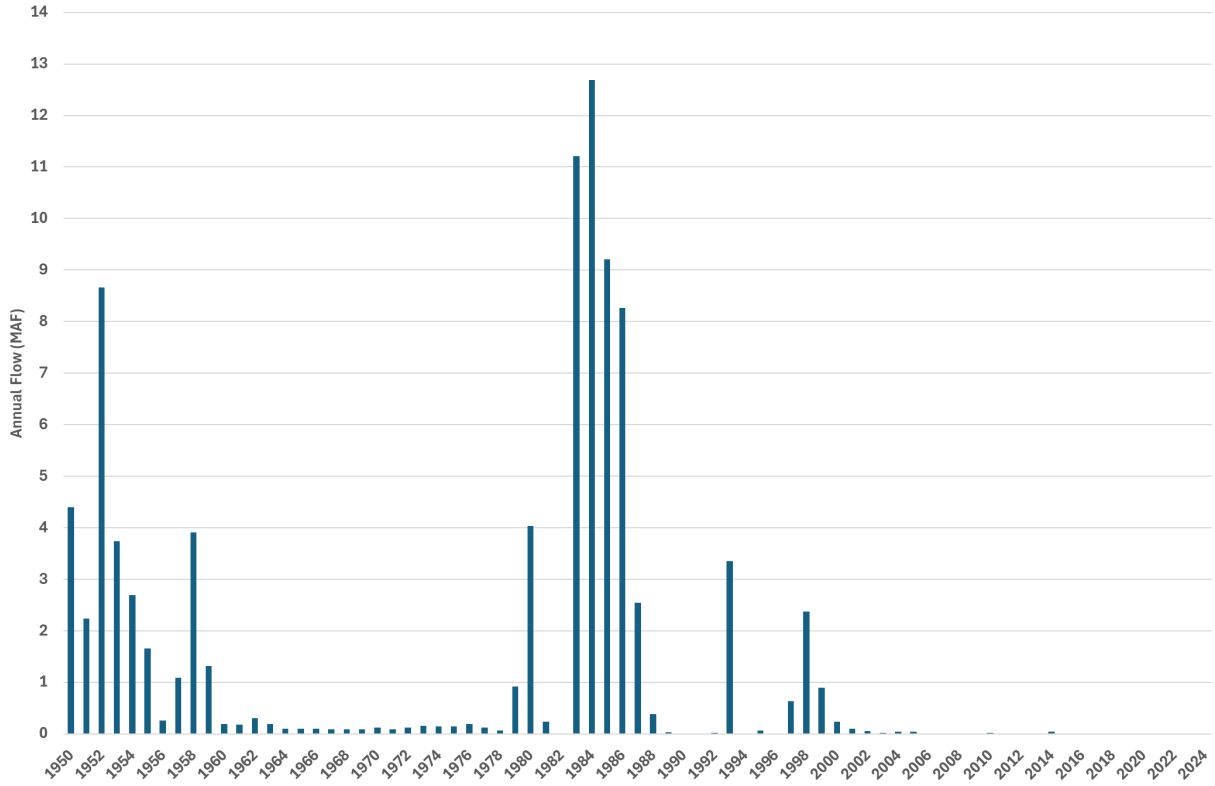
Groundwater below the riverbed is recharged from irrigated fields in the Yuma area to the east and from Mexico's irrigation fields and seepage from the Reforma Canal to the west. The depth to groundwater increases from north to south. In the upper reaches, the relatively high-water table allows for perennial flows to exist, while the water table declines significantly towards the SIB (Ramírez-Hernández et al. 2013; Cohen 2013). Low moisture conditions in the root zones make surface vegetation sparse; however, by tapping into pumped groundwater in both countries and delivering water from canal infrastructure in Mexico, several restoration efforts exist along both sides of the riverbanks, such as Gadsden Bend, Miguel Aleman, Janitzio and Hunters Hole. These sites seek to re-establish and maintain vegetation along the riparian corridor in the Limitrophe and enhance habitat conditions for migratory and non-migratory birds and terrestrial species. A study of the composition of avian populations in the Colorado River Delta region demonstrates the high influence of the plant communities and land cover on the variability of bird species, as well as a positive relationship between cover of native riparian trees and shrubs and bird species with an

affinity for riparian forests (Gonzales-Sargas et al. 2024). Two of the five focal reaches of this study are within the Limitrophe.

An extensive study conducted by Cohen (2013) indicated that groundwater conditions had deteriorated over the 57 years prior to their study. While upper reaches showed relatively steadier groundwater elevations, the deterioration was particularly noted in the lower reaches of the Limitrophe where water table elevations dropped around 27 feet between 1960 and 2009. This decline was attributed to several factors, including the decrease of surface flows downstream from Morelos Dam, diminishing groundwater recharge, and increased well pumping along the Arizona-Sonora border. As water tables decline further, resulting in decreasing unmanaged vegetation, the relative value of restoration areas to maintain a riparian habitat increases, such as Gadsden Bend, Miguel Aleman, Janitzio, and Hunters Hole.

Flows reaching the SIB through the Limitrophe have been substantial in past years (**Figure N-2**). Notably in the 1980s, flood control releases from Lake Mead allowed over 12 million acre-feet (maf)/year (14,800 million cubic meters [mcm]/year) to be discharged through the Morelos Dam and down into the Colorado River Delta. In recent decades this flow has been minimal. As a product of Minute 319, an environmental pulse flow of approximately 105,392 acre-feet (af) was released below Morelos Dam in 2014 to mimic a spring flood flow that reached the Sea of Cortez (Pitt et al. 2017).

Figure N-2
Colorado River Channel at Southerly International Boundary (SIB)



Sources: IBWC 1960-2024; USGS 2025b; Glenn et al. 2008

N.2.2 Previous Binational Coordination

The U.S. and Mexico have a long history of cooperation and coordination with respect to the Colorado River, most notably starting with the 1944 Water Treaty. This treaty guarantees an annual quantity of 1.5 maf (1,850 mcm) to Mexico from the Colorado River under normal conditions, with the potential for up to a total of 1.7 maf (2,100 mcm) during times when surplus waters are available. It also provides for reduced volumes to Mexico under extraordinary drought.

The precise text of the 1944 Water Treaty is as follows:

Article 10(a) of the 1944 Water Treaty states:

> "(a) A guaranteed annual quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty"

Further, Article 10(b) of the 1944 Water Treaty states:

> "(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 acre-feet (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of waters of the Colorado River system, for any purpose whatsoever, in excess of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually."

Additionally, Article 10 of the 1944 Water Treaty states:

> "In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced."

Since the 1944 Water Treaty was signed, a series of implementing agreements, or Minutes, have been agreed upon and signed to facilitate cooperation between the countries. Some of them are of particular relevance to the issues analyzed in this EIS.

Salinity of water is an important concern to users in the Lower Basin including those in the U.S. and Mexico. While some salinity sources naturally exist throughout the Colorado River Basin, agricultural return flows, that are often high in salinity, enter the Colorado River through surface and groundwater pathways. As a result of salinity accumulation, diversions downstream along the Colorado River mainstem are increasingly impacted relative to diversions upstream. Diversions taken by Mexico are often subject to the highest salinity concentrations. This concern over salinity led to Minute 242 of the 1944 Water Treaty.

Resolution 1(a) of Minute 242 explicitly address the salinity concerns of Mexico stating:

> "The United States shall adopt measures to assure that not earlier than January 1, 1974, and no later than July 1, 1974, the approximately 1,360,000 acre-feet (1,677,545,000 cubic meters) delivered to Mexico upstream of Morelos Dam, have an annual average salinity of no more than 115 p.p.m. ± 30 p.p.m. U.S. count (121 p.p.m. ± 30 p.p.m. Mexican count) over the annual average salinity of Colorado River waters which arrive at Imperial Dam, with the understanding that any waters that may be delivered to Mexico under the Treaty of 1944 by means of the All American Canal shall be considered as having been delivered upstream of Morelos Dam for the purpose of computing this salinity."

Today Reclamation meets the obligation of the U.S. to not violate this differential through several different means, including bypassing saline waters through the Main Outlet Drain Extension (MODE) canal around agricultural, municipal, and industrial systems in the U.S. and Mexico and blending water arriving at the NIB through additional upstream releases.

In 2012, the U.S. and Mexico signed Minute 319 to the 1944 Water Treaty, titled *Interim International Cooperative Measures in the Colorado Rier Basin Through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California.* This Minute established four coordination mechanisms that affected flows in the International Border Region of the Colorado River:

- Based on the framework established in the Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a) following the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 Interim Guidelines; Reclamation 2007b), Mexico agreed to reduced deliveries during times of low reservoir elevation conditions, defined by projected pool elevations of Lake Mead falling below specified thresholds. Three tiers of reductions were defined as "50,000 acre-feet (62 mcm) when the January 1 Lake Mead elevation is projected to be at or below 1,075 feet msl and at or above 1,050 feet msl; 70,000 acre-feet (86 mcm) when the January 1 Lake Mead elevation is projected to be below 1,050 feet msl and at or above 1,025 feet msl; and 125,000 acre-feet (154 mcm) when the January 1 Lake Mead elevation is projected to be below 1,025 feet msl." These low elevation thresholds align with those used to trigger shortages to users in Lower Division States and the volumes of reductions to Mexico were selected generally in proportion to shortage commitments by the Lower Division States in the 2007 Interim Guidelines. Minor adjustments were made to a strict proportionality to accommodate Mexico's preference for lower reductions under less severe conditions and greater reductions under more critical circumstances.
- Water deliveries to Mexico would increase during high elevation reservoir conditions as defined by projected pool elevations of Lake Mead at or above 1,145 feet, at or above 1,170 feet, and at or above 1,200 feet. In each of these cases, increases to annual releases to Mexico of 40.0 kaf (49 mcm), 55.0 kaf (68 mcm), and 80.0 kaf (99 mcm) respectively would be made. Only when flood control releases are required, Mexico would receive an annual increase of up to 200.0 kaf (247 mcm) not to exceed a total of 1.7 maf. The thresholds and

the volumes of flows under high elevation reservoir conditions also mirrored those of Lower Division States.

- Extending an emergency measure put into place as Minute 318 (Adjustment of Delivery Schedules for Water Allotted to Mexico for the Years 2010 Through 2013 as a Result of Infrastructure Damage in Irrigation District 014, Rio Colorado, Caused by the April 2010 Earthquake in the Mexicali Valley, Baja California) that followed an earthquake in April 2010, which damaged Mexico's irrigation infrastructure, Minute 319 established a conservation and storage mechanism, known as Intentionally Created Mexican Allocation, by which Mexico could defer delivery of a portion of their annual allotment of Colorado River water and deliver that water in a future year. This mechanism mirrored a similar program of Intentionally Created Surplus that allows U.S. users in Lower Division States to store water from one year to the next. Both the programs were established with clear rules for depositing and withdrawing water.
- Under the spirit of binational cooperation, a pilot program was initiated to dedicate water to enhance the environmental condition in the Colorado River Delta including its Limitrophe. Water created by conservation measures in Mexico and deferred in the U.S. system provided water for a 105,068 af (129.6 mcm) flow released from Morelos Dam on behalf of the U.S. and Mexican governments. A binational coalition of non-government organizations delivered a proportional amount through Mexico's irrigation canals to targeted restoration areas. Concurrently, this mechanism established the ability for 124,000 af (153 mcm) of water conserved as Intentionally Created Mexican Allocation to be transferred to Lower Division States' Intentionally Created Surplus accounts and used in the U.S..

The term of Minute 319 was 5 years, expiring on December 31, 2017. Prior to its expiration, Minute 323 was signed and entered into force on September 27, 2017, which built on and extended provisions of Minute 319 and added a complementary program to the Lower Basin Drought Contingency Plan until December 31, 2026. Titled the *Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin*, Minute 323 provided a number of actions as follows:

- Reductions to deliveries to Mexico during low elevation Lake Mead reservoir conditions as specified in Minute 319 were extended.
- Additional deliveries to Mexico during high elevation Lake Mead reservoir conditions as specified in Minute 319 were extended.
- A Binational Water Scarcity Contingency Plan was established that provides for each country to save specified volumes of water at certain low reservoir elevations for recovery at a later date when reservoir conditions improve. Elevation thresholds for Mexico contributions match those developed in the *2019 Colorado River Drought Contingency Plans* (Reclamation 2019), and volumes of savings contributions by Mexico match the percent of additional saved contributions above the required reductions by Lower Division States at each elevation tier.
- A Mexico Water Reserve expands on and incorporates volumes previously stored in the accounts established in Minute 318 and 319, incorporates water retained from any future emergency measures, and provides a mechanism to defer delivery of a portion of Mexico's

annual water allocation through 2026. Delivery and deferral provisions are included in Minute 323.

- Expansion of restored native habitat in the Colorado River Limitrophe and Delta with 210,000 af of water, alongside funding for scientific research and monitoring, and funding for environmental enhancement projects. These elements were provided through equal contributions of the two Federal Governments and a binational coalition of non-governmental organizations, each of which would provide 1/3 of the required funding and water through conservation projects.
- In addition to the 70,000 af of water provided by the U.S. for native habitat enhancement, funding for conservation measures in Mexico would also provide 50,000 acre-feet (62 mcm) of water for the benefit of all users and 109,100 af (135 mcm) of water for use in the U.S.

Concurrent to the implementation of the *Supplement to the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Record of Decision*, (Reclamation 2024a) following the *Near-term Colorado River Operations Final Supplemental Environmental Statement* (Reclamation 2024b) in March 2024, Minute 330, titled *Expansion of Colorado River Temporary Measures*, was signed between the U.S. and Mexico that requires Mexico to conserve 400.0 kaf between 2023 and 2026, which were in addition to conservation requirements specified in Minute 323. Of this amount, at least 250.0 kaf is water for the Colorado River system, and the remainder is for Mexico's Water Reserve. Any volume in Mexico's Water Reserve shall remain there through December 31, 2026.

N.2.3 Environmental Enhancement Activities

Continuing the binational collaboration initiated in Minute 306 (*Conceptual Framework for United States – Mexico Studies for Future Recommendations Concerning the Riparian and Estuarine Ecology of the Limitrophe Section of the Colorado River and its Associated Delta*), Minute 319 and Minute 323 operationalized environmental cooperation regarding the Colorado River Delta including the shared Limitrophe. Pilot efforts to plan and design water releases through the Limitrophe as well as enhance habitat conditions through re-vegetation have provided in-situ testing of restoration approaches. Over many decades much of the native habitat that was once found in the Limitrophe region is no longer present, or greatly degraded, due to a variety of factors including fire, mechanical removal, and lack of water. In the Limitrophe most of the native habitat now present is in the form of managed restored sites that are irrigated with groundwater or receive water via Mexico's diversion at Morelos Dam. Groundwater dependent sites are not expected to be affected by any changes in the system as the groundwater source and the sites themselves are actively managed independent of surface flows. Sites dependent on diversion infrastructure through Mexico will be affected by site maintenance activities, and the volume of water delivered to these habitat restoration sites will be affected to some extent by the total volume of water delivered to Mexico. The modeled annual deliveries (i.e. depletions) to Mexico include assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and

implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The Minute 319 pulse flow of 2014 inundated approximately 4,000 acres (1,600 hectares) of the main channel and adjacent terraces of the Colorado River Delta, achieving connectivity to the Sea of Cortez for the first time since 2001 (Pitt et al. 2017). The pulse flow did not widen the channel or significantly result in geomorphic changes such as scouring sediments beyond 1 meter or bury existing vegetation. However, it did temporarily elevate water tables by as much as 9 meters (30 feet) locally and produced a 17 percent increase in Normalized Difference Vegetation Index (NDVI) or "Greenness" throughout the riparian corridor during the following growing season. This elevated NDVI decreased to pre-pulse levels in most reaches by 2017 and all reaches by 2018 (IBWC 2018; 2022). Although significant amounts of water infiltrated into the dry streambed and only a small amount of water reached the Sea of Cortez, the pulse flow of 2014 helped to reverse a decline in evapotranspiration from 2011 to 2013 (Jarchow et al. 2017a, 2017b).

Following targeted restoration efforts of Minute 323, Nagler et al. (2022) reported positive results measured by Landsat images of two-band Enhanced Vegetation Index (EV12) and evapotranspiration indicators (EVI2 and potential ET (ETo)), while non-restored areas declined notably. Furthermore, bird diversity and abundance of indicator species were 20 percent and 74 percent higher, respectively, in the restoration sites than in unrestored control sites (IBWC 2022). These studies assess conditions across sites throughout the Colorado River Delta, which include sites along the Limitrophe as well as locations outside of the geographic scope of this EIS.

N.2.4 Limits of Analysis

The proposed federal action is for the purpose of adopting additional operational guidelines to improve Reclamation's annual management and operation of key Colorado River reservoirs for an interim period. The scope is limited to evaluating potential impacts of the various alternatives within the U.S. and the Limitrophe reach shared with Mexico. The impacts within Mexico, including reaches downstream of the Limitrophe, are outside of the scope of this EIS. However, to assess the potential effects of the proposed federal action in this EIS, certain model assumptions are used that would potentially affect estimated water deliveries and flows into Mexico. Such modeling assumptions are used regarding the volume of water deliveries to Mexico as well as potential water releases for the Limitrophe as specified by the alternatives being considered.

Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

N.3 Methodology

This appendix compiles and describes a collection of analyses throughout the Environmental Impact Statement that pertain to the International Border Region. This Appendix primarily gathers results

from relevant Technical Appendices including **TA 3**, Hydrologic Resources, **TA 4**, Water Deliveries, and **TA 6**, Water Quality and presents them in a format to show the relative impacts of the proposed alternatives for Mexico, given the assumptions described in **Section N.3.2** and elsewhere. **Chapter 2** and **Appendix S** describes the alternatives that are simulated, **Appendix A**, CRSS Model Documentation, describes the CRSS modeling process and assumptions in detail, and **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, describes the use of the Shortage Allocation Model and Alternative Distribution Models. Refer to those sections for an understanding of the overall modeling processes. Assumptions and terminology used that are unique to the results provided for the International Border Region are described below.

N.3.1 Impact Indicators

Three key areas are considered when evaluating the impacts in the International Border Region. These include the following:

- Impacts on water deliveries and reductions to deliveries to Mexico (equivalent to shortages to Lower Division State users)
- Impacts on salinity/total dissolved solids
- Impacts on hydrologic flows in the Limitrophe

Hydrologic flows in Limitrophe are used as a proxy for environmental conditions in this river reach shared by the U.S. and Mexico.

N.3.2 Assumptions for the International Border Region

N.3.2.1 Colorado River Simulation System (CRSS)

Aspects unique to the international border region, including terminology used, are described in this section. The general assumptions in CRSS are described in **Appendix A**, CRSS Model Documentation.

Deliveries and reductions to Mexico

The relationship between water deliveries and reductions for Mexico is as follows:

Mexico's annual allotment (1.5 maf)	=	Annual water delivery to Mexico	+	Annual water delivery reduction to Mexico

The annual delivery reduction to Mexico can be the result of a policy explicitly specified in an alternative, described hereafter as a *water delivery reduction* for Mexico (as opposed to a shortage as used for Lower Division States) or Lake Mead reaching critically low elevations when the volume of water that can be released from Hoover Dam is insufficient to meet all downstream demands. In this case, modeling assumptions are made to further reduce water deliveries to users in what is termed a dead pool-related reduction. The combination of a water delivery reduction for Mexico and a dead pool-related reduction for Mexico comprises the total water delivery reductions for Mexico.

Total annual water delivery reduction to Mexico	=	Water delivery reduction to Mexico	+	Dead pool-related reduction to Mexico

In all alternatives, both types of water delivery reductions to Mexico occur simultaneously with the equivalent reductions to deliveries to Lower Division States (i.e., shortages). When shortages occur in the Lower Division States, reductions simultaneously occur for Mexico's water deliveries. In all alternatives, except for the Continued Current Strategies (CCS) Comparative Baseline[3], 16.67 percent of any shortage for the entirety of the Lower Basin is applied to Mexico on an annual basis. A comparison of the effects of varied assumptions is provided in **Appendix K**, Sensitivity Analysis – Effects of Modeling Assumptions with Regard to Future Water Deliveries to Mexico.

Lower Basin Shortages (100 percent)	=	Shortages to Lower Division States (83.33 percent)	+	Water Reductions to Mexico (16.67 percent)

There are no guarantees that shortages will be sufficient to keep Lake Mead from approaching dead pool when the water available is insufficient to meet downstream demands, so in this case, dead pool-related reductions are applied to users in Mexico concurrently with users in the Lower Division States. In all alternatives, including the CCS Comparative Baseline, 16.67 percent of any required basin-wide dead pool-related reduction is applied to Mexico as a water delivery reduction on a monthly basis.

Lower Basin dead pool-related reductions (100 percent)	=	Dead pool-related Reductions to Lower Division States (83.33 percent)	+	Dead pool-related Reductions to Mexico (16.67 percent)

The assumption of 16.67 percent of any Lower Basin shortage or dead pool-related reduction being applied to Mexico occurs regardless of the allocation method used among water users within the U.S.. The value of 16.67 percent reflects the fraction of water allocated to Mexico (1.5 maf) relative to the combined allocation for the Lower Division States and allotment to Mexico (9.0 maf).

Salinity Assumptions

CRSS includes salinity tracking capability, which was introduced specifically for the purpose of the International Border Region analyses in this EIS. Using an equation developed by the U.S. Geological Survey (USGS 2018), which can be classified as a hybrid between a mechanistic and statistical model, salinity at Imperial Dam is calculated as a function of Hoover Dam salinity, Parker Dam releases, and diversions by Colorado River Indian Reservation and Palo Verde Irrigation District . Salinity at the NIB is calculated as a function of simulated salinity at Imperial Dam and assumed monthly base flows accruing to the Colorado River between Imperial Dam and the NIB.

[3] The only exception to the consistent approach of applying 16.67 percent of shortages to Mexico is in the CCS Comparative Baseline. In this case reductions to Mexico's water deliveries follow logic derived from Minute 323 including Mexico's contributions to the Binational Water Scarcity Contingency Plan. This provides a point of comparison and is not considered an alternative in this EIS.

While CRSS does simulate flows between Imperial Dam and NIB, historical, average monthly base flows between Imperial Dam and the NIB are specified and used for the sole purpose of estimating salinity at NIB.

The base flows accruing to the river between Imperial Dam and NIB, which are used to estimate the salinity at the NIB, vary for each month but are the same for every year of the analysis. Base flow data includes monthly average volume and salinity estimated using historical data from the period of 2018 through 2022. Base flows include uncontrolled and unmeasured return flows from groundwater, measured irrigation return flows and canal wasteway flows, discharges to the Colorado River from pumped groundwater originating in the South Gila Valley and discharging through the Drainage Pump Outlet Channels, and pumped groundwater from the Yuma Mesa, Yuma Valley, and eastern end of the 242 Well Field, which discharge to the Colorado River by way of the Yuma Mesa Conduit. The salinity at the NIB is calculated via a simple monthly mass balance using the volume of Colorado River water delivered to Mexico by way of Imperial Dam (using the associated Imperial Dam salinity value) plus the base flows and their associated salinity values. The analysis conducted for this EIS does not include simulated operations by Reclamation's Yuma Area Office to ensure compliance with the Minute No. 242 salinity differential (IBWC 1973). A sensitivity analysis was conducted to evaluate how varying the assumed volume of pumped groundwater used to meet Mexico's delivery, within the constraints of CRSS, affects Lake Mead elevations (See **Box 1**). The NIB salinity data provided in this appendix should not be used as projected actual salinity at NIB but instead used to compare alternatives.

Environmental Enhancement Releases

Regarding alternatives that specify releases for habitat enhancement in the Colorado River Delta, water could be provided as discharges into the Limitrophe through or around the Morelos Dam or as additional diversions to Mexico that are strategically discharged back into the Limitrophe or further downstream to support enhancement efforts. For modeling purposes used in this EIS, water dedicated for environmental enhancement is assumed to be diverted by Mexico at the Morelos Dam and reflected as periodic additions to Mexico's diversion and not as flows downstream of the Morelos Dam or flows in the Limitrophe.

N.3.2.2 Shortage Allocation Models and Alternative Distribution Models

In the spreadsheet models used by Reclamation to represent the allocation of shortages to individual Lower Basin water users, the reduction volumes assigned to Mexico are identical to those in CRSS but use slightly different approaches depending on assumptions of priority vs. pro rata allocation schemes. In priority-based Shortage Allocation Models (SAM) and Alternative Distribution Models (ADM), the basin-wide shortage is separated into shortages to Lower Division States and water delivery reductions to Mexico so that the percent reduction from full allocation or allotment (7.5 maf and 1.5 maf) is identical, which is similar to the process used in CRSS. In the various pro rata ADMs, each user in the Lower Division States is reduced by a proportion of either the basin-wide shortage or state-wide shortages based on the total consumptive use of that user relative to the basin-wide or state-wide uses. In all cases, water delivery reductions allocated to Mexico are then simply the remainder of basin-wide shortages not allocated to the Lower Division States. In all variations of the SAMs and ADMs, the allocation of basin-wide water delivery reductions to Mexico is 16.67 percent, which is identical to the assumption used in CRSS, notwithstanding minor variation

in rounding. Refer to **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, for further information about the SAMs and ADMs.

N.4 Relevant Results

N.4.1 Issue 1: Water Deliveries and Reductions to Mexico

Water Deliveries to Mexico are described in **TA 4**, Water Deliveries, and summarized here. Water deliveries to Mexico are a function of assumed reductions to Mexico and assumptions about the deferral and delivery of conserved water to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

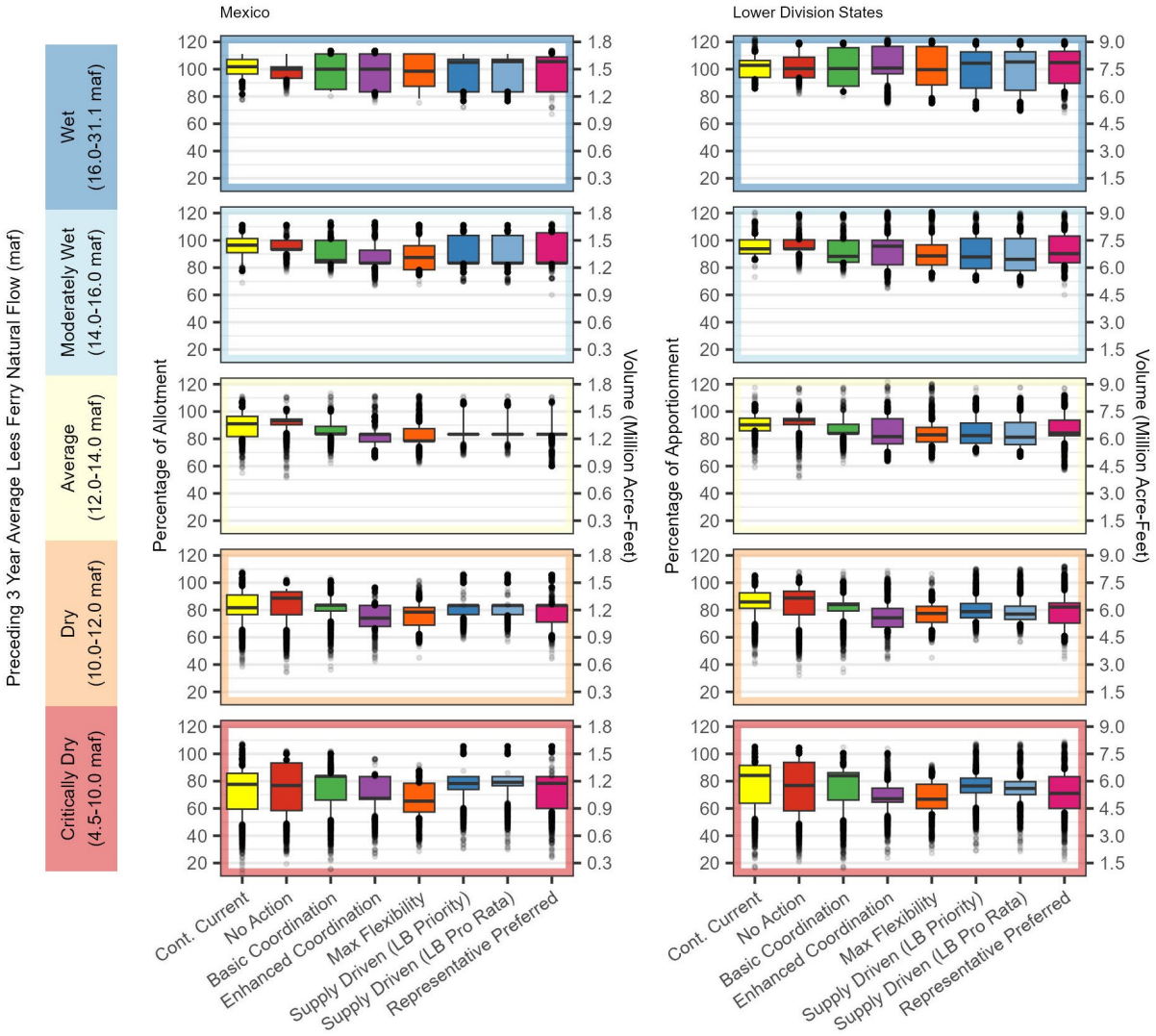
N.4.1.1 Distributions of annual water deliveries to Mexico and Lower Division States

Figure N-3 presents conditional box plots of water deliveries to Mexico in comparison to deliveries to the combined Lower Division States of California, Arizona and Nevada. These deliveries reflect both the depletions from the river system after shortages (i.e. water delivery reductions) and dead pool-related reductions, which have been subtracted from the total allotments of 1.5 maf for Mexico and 7.5 maf from the Lower Division States. Deliveries (i.e. depletions) also account for modeling assumptions related to voluntary conservation mechanisms. The deliveries are broken out by different hydrologic conditions, categorized by modeled preceding 3-year average Lees Ferry natural flows. The hydrologic analysis is framed using 5 flow categories to help to visualize the different potential states of the system throughout the 34-year period of analysis. The 5 flow categories are: Wet (16-31.11 maf), Moderately Wet (14.0-16.0 maf), Average (12.0-14.0 maf), Dry (10.0-12.0 maf), and Critically Dry (4.46-10.0 maf). Each box plot represents the distribution of modeled outputs, with a horizontal line indicating the median value, the colored box indicating the range of values from the 25th to 75th percentile, the extent of the lines indicating the 10th and 90th percentiles, and circles representing values below the 10th and above the 90th percentiles (See **Chapter 3, Figure 3-2** for a detailed description). The value of the left-hand vertical axes of the figure represents the percent of full allotment (terminology for Mexico) or apportionment (for Lower Division States), therefore in the plot of deliveries for Mexico, 100 percent indicates when Mexico is receiving the annual 1.5 maf of delivery as specified in the 1944 Water Treaty, and in the plot for Lower Division States, 100 percent indicates when these states are receiving 7.5 maf. Scaling the vertical axis by percent allotment or apportionment allows direct comparability between Mexico and the Lower Division States regarding the implications of the alternatives.

To evaluate the relative implications of the alternatives on deliveries to Mexico, an initial focus is on the Average Flow Category (12.0-14.0 maf preceding 3-year average), where the median percent of full allotment ranges from the least impactful No Action Alternative (93.3 percent) to the most impactful Maximum Operational Flexibility Alternative (78.5 percent), with all other alternatives between this narrow range including the Representative Preferred Alternative with 83.3 percent. In the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average), the median percent of

full allotment ranges from the least impactful Basic Coordination Alternative (83.6 percent) to the most impactful Maximum Operational Flexibility Alternative (65.4 percent), with all other alternatives between this expanding range including the Representative Preferred Alternative with a median of 78.4 percent.

Figure N-3
Conditional Box Plots of Calendar Year Water Deliveries to Mexico and Lower Division States



Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

These values for Mexico are comparable to those of the combined Lower Division States, which in the Average Flow Category (12.0-14.0 maf preceding 3-year average) the median percent of full allocation ranges from the least impactful No Action Alternative (93.8 percent) to the most impactful Supply Driven Alternative (LB Pro Rata approach) (81.2 percent) with the Representative Preferred Alternative with 84.2 percent. Similarly, for the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average) the median percent of full allocation ranges from the least impactful CCS Comparative Baseline (84.2 percent) to the most impactful Maximum Operational Flexibility Alternative (66.8 percent), with the Representative Preferred Alternative providing a median of 71.0 percent of full allocation to Mexico.

Although Mexico's percent of total Lower Basin shortage or dead pool-related reductions is fixed as 16.67 percent among all the alternatives (except for the CCS Comparative Baseline), this does not necessarily equate to identical depletions as a percent of allotment (i.e. apportionment) of reductions between the Lower Division States and Mexico. This is due to varied assumptions on storage mechanism parameters and activity between Mexico and the Lower Division States, and the monthly application of dead pool-related reductions (Note: As seen in a subsequent analyses, annual water delivery reductions (i.e. shortages) are identical as a percent of allotment (or apportionment) for Mexico and the Lower Division States). A comparison of median values of annual depletions under the Average and Critically Dry hydrologic categories is shown in **Table N-1**.

Table N-1
Annual depletions in Mexico and Lower Division States (as a percent of allotment or apportionment) at the median value of years in the average (12.0-14.0 maf preceding 3-year average) and critically dry (4.46-10.0 maf preceding 3-year average) hydrologic categories.

	Average Flow Category (12.0-14.0 maf preceding 3-year average)		Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average)	
	Mexico	Lower Division States	Mexico	Lower Division States
Cont. Current	91.0	90.2	77.7	84.2
No Action	93.3	93.8	76.8	76.8
Basic Coordination	83.6	84.0	83.6	84.0
Enhanced Coordination	83.3	81.6	67.4	67.1
Max Operational Flexibility	78.5	82.9	65.4	66.8
Supply Driven (LB Priority)	83.3	82.4	78.3	76.5
Supply Driven (LB Pro Rata)	83.3	81.2	79.2	74.7
Representative Preferred	83.3	84.2	78.4	71.0

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Due to the design of the No Action and Basic Coordination Alternatives having the lowest maximum shortages (0.6 maf and 1.48 maf respectively), these alternatives result in the lowest impact on diversions to Mexico or the Lower Division States, but at the cost of the largest impact on reservoir storage (See **TA 3, Hydrologic Resources, Figure TA 3-18**). The CCS Comparative Baseline has a similarly low maximum shortage (1.38 maf), but these levels of shortage do not begin until Lake Mead is below 1,025 feet. The Maximum Operational Flexibility Alternative has the highest maximum possible shortage (4.0 maf), thus resulting in the highest median impacts on Mexico under these two flow categories of 12.0-14.0 maf and 4.46-10.0 maf preceding 3-year average.

The variability of deliveries during dry conditions is another metric by which to evaluate the alternatives. To do this, the interquartile range (boxed areas representing the range from the 25th to 75th percentiles in **Figure N-3**) is evaluated within the Critically Dry Flow Category (4.46-10 maf). To provide an example calculation for the CCS Comparative Baseline for Mexico in this Hydrologic Category, the 75th percentile (85.7 percent of allotment) minus the 25th percentile (59.5 percent of allotment), results in a 26.2 percent interquartile range (See **TA 4, Water Deliveries, Table TA 4-39** for all percentiles in **Figure N-3**). Three distinct groupings of alternatives are apparent (**Table N-2**). The CCS Comparative Baseline and the No Action Alternative have the widest interquartile ranges (26.2 percent and 34.9 percent respectively for Mexico, and 27.7 percent and 35.5 percent for the Lower Division States). The Basic Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives all have similar interquartile ranges (between 17.4 percent and 23.3 percent for Mexico and 17.8 percent and 23.3 percent for the Lower Division States). The Supply Driven Alterative has the narrowest interquartile range, with 9.4 percent and 6.7 percent for the Lower Basin Priority (LB Priority) and Lower Pasin Pro Rata (LB Pro Rata) distribution approaches respectively for Mexico, and 10.7 and 9.5 for the Lower Division States. The Enhanced Coordination Alternative spans across the narrowest and mid-range group of alternatives, with 16.7 and 10.3 percent for Mexico and Lower Division States respectively. Several factors affect the sizes of the interquartile ranges. In general, the narrower the variability, the more consistent the releases are to meet demands, which is substantially influenced by the design of the alternatives including the maximum specified shortage, the slope of the shortage operation curve, and the use of conservation and storage mechanisms that help to even out water deliveries. The alternatives with low maximum specified shortages (No Action, Basic Coordination Alternatives, and CCS Comparative Baseline) often lead to dead pool-related reductions, which result in highly variable reductions of use and therefore highly variable annual depletions. Furthermore, these same alternatives have no or minimal storage mechanisms, resulting in less mitigation ability and greater variability of flows near the median. On the other extreme, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the large Lower Basin storage mechanisms, resulting in the small interquartile ranges and low variability around the median. This highlights the benefits of conservation and storage mechanisms to reduce variability in water deliveries. Finally, the Representative Preferred Alternative has a wide interquartile range, despite the specification of a high maximum specified shortage and a large Lower Basin storage mechanism, because of the significant slope of the shortage curve at low reservoir elevations, quicky ranging from 1.5 maf to 3.6 maf between Lake Mead elevations of 1,025 and 975 feet.

Table N-2
Interquartile range of annual depletions (as a range between the 75th and 25th percentile, reported as percent of allotment or apportionment) for Mexico and Lower Division States at the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average).

	Interquartile range	
	Mexico	Lower Division States
Cont. Current	26.2	27.7
No Action	34.9	35.5
Basic Coordination	17.4	20.1
Enhanced Coordination	16.7	10.3
Max Operational Flexibility	21.1	17.8
Supply Driven (LB Priority)	9.4	10.7
Supply Driven (LB Pro Rata)	6.7	9.5
Representative Preferred	23.3	23.3

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Looking further into the distributions under the Critically Dry Flow Category (4.46-10.0 maf) (**Table N-3),** all alternatives show the possibility of deliveries to Mexico being reduced to extremely low percentages of their 1.5 maf apportionment, ranging from a minimum of 12.7 percent and 15.2 percent of apportionment (corresponding to 0.19 maf and 0.23 maf of total deliveries to Mexico) under the Current Continued Strategies and the Basic Coordination Alternative respectively, to a 30.5 percent of apportionment (0.46 maf) for the Supply Driven Alternative (LB Priority approach). The minimum delivery to Mexico under the Representative Preferred Alternative is 24.1 percent of apportionment (0.36 maf).

Table N-3
Annual depletions in Mexico (as a percent of allotment) at the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average)

	Percentile						
	max	90th	75th	50th	25th	10th	min
Cont. Current	107.1	91.0	85.7	77.7	59.5	48.6	12.7
No Action	101.7	94.4	93.3	76.8	58.4	49.1	19.4
Basic Coordination	101.7	85.2	83.6	83.6	66.1	51.8	15.2
Enhanced Coordination	96.3	83.3	83.3	67.4	66.7	54.9	24.6
Max Operational Flexibility	92.1	78.5	78.5	65.4	57.4	53.2	28.6
Supply Driven (LB Priority)	105.6	83.3	83.3	78.3	73.9	60.5	30.5
Supply Driven (LB Pro Rata)	105.6	83.3	83.3	79.2	76.7	63.9	29.7
Representative Preferred	105.6	83.3	83.3	78.4	60.0	57.9	24.1

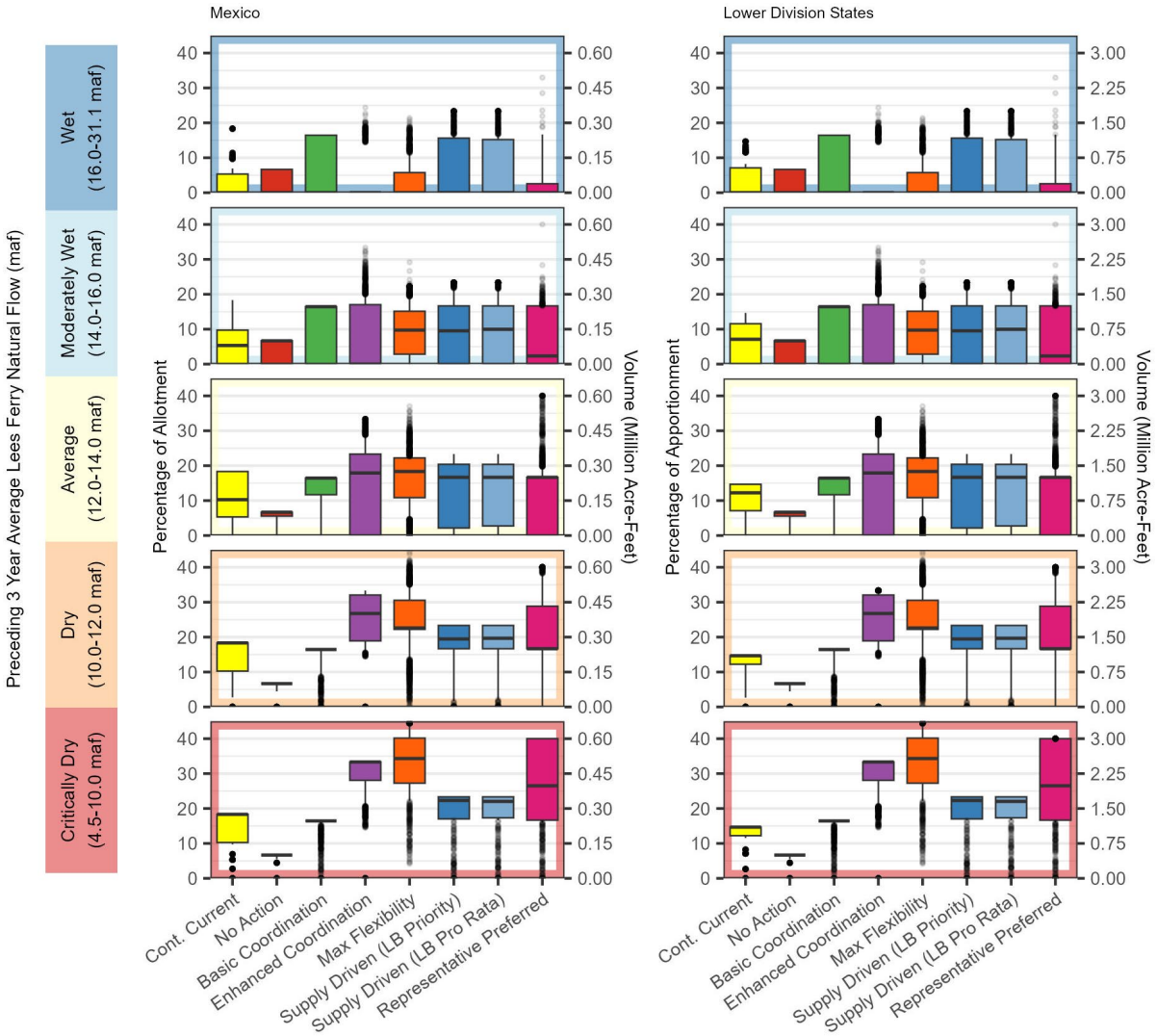
Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

N.4.1.2 Distributions of annual water delivery reductions to Mexico and Lower Division States

Using the same 5 preceding hydrologic flow categories to help to visualize the different potential states of the system throughout the 34-year period of analysis, **Figure N-4** shows the volume of water delivery reductions to Mexico alongside those of the combined Lower Division States. Due to the differences in magnitudes of use and corresponding shortages between Mexico and the Lower Division States, the left-hand axes show the percent of allotment or apportionment to allow comparability, and the right-hand axes show the volumes of water delivery reductions.

The magnitude of water delivery reductions to Mexico reflects the design of the policies as well as the hydrologic conditions but does not reflect any dead pool-related reductions which are significant under alternatives with limited specified Lower Basin shortages. Under the Average Flow Category (12.0-14.0 maf preceding 3-year average), the Maximum Operational Flexibility Alternative results in the largest median reduction value of 18.3 percent of apportionment for Mexico (**Table N-4**). The Enhanced Coordination is similar with a median value of 17.9 percent. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives all have median values of 16.7 percent of Mexico's apportionment. In contrast, both baselines reflect low water delivery reductions with the CCS Comparative Baseline resulting in a median of 10.3 percent and the No Action Alternative with a median of 6.7 percent of the apportionment to Mexico, while the Basic Coordination Alternative results in a median reduction of 16.4 percent of the apportionment to Mexico. However, these three alternatives result in more frequent dead pool-related shortages as described in a subsequent analysis.

Figure N-4
Conditional Box Plots of Calendar Year Delivery Reductions to Mexico and Lower Division States



Note: The modeled annual delivery reductions to Mexico include assumptions that are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table N-4
Water delivery reductions (as percent of allotment or apportionment) for Mexico and Lower Division States at the median value of years in the Average (12.0-14.0 maf preceding 3-year average) and Critically Dry (4.46-10.0 maf preceding 3-year average) Flow Categories.

	Average Flow Category (12.0-14.0 maf preceding 3-year average)		Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average)	
	Mexico	Lower Division States	Mexico	Lower Division States
Cont. Current	10.3%	12.2%	18.3%	14.7%
No Action	6.7%	6.7%	6.7%	6.7%
Basic Coordination	16.4%	16.4%	16.4%	16.4%
Enhanced Coordination	17.9%	17.9%	33.3%	33.3%
Max Operational Flexibility	18.3%	18.3%	34.3%	34.3%
Supply Driven (LB Priority)	16.7%	16.7%	22.3%	22.3%
Supply Driven (LB Pro Rata)	16.7%	16.7%	22.0%	22.0%
Representative Preferred	16.7%	16.7%	26.5%	26.5%

Note: The modeled annual delivery reductions to Mexico include assumptions that are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Under the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average), the largest median water delivery reduction to Mexico occurs using the Maximum Operational Flexibility Alternative with a median of 34.3 percent of the apportionment to Mexico followed by the Enhanced Coordination Alternative with a median of 33.3 percent. The alternative with the lowest median water delivery reduction is the No Action Alternative (6.7 percent); however, as shown below, this low water delivery reduction results in the lowest avoidance of dead pool-related reductions. The Representative Preferred Alternative results in a median water delivery reduction to Mexico of 26.5 percent of their 1.5 maf allotment, or 0.40 maf.

The median water delivery reductions by a percent of apportionment are identical between Mexico and the Lower Division States under all alternatives (**Table N-4**). The one exception is the CCS Comparative Baseline, which is the result of current policies derived from the combination of actions specified in Minute 319 and Minute 323 for Mexico, and the combination of actions specified in the 2007 Interim Guidelines and 2019 Lower Basin Drought Contingency Plan for the Lower Division States.

Figure N-4 also shows the implications of proactive versus delayed water delivery reductions to both the Lower Division States and Mexico. The comparatively wide interquartile range of the Representative Preferred Alternative in the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average) suggests that under these dire conditions, there is little predictability in the required

reductions to water use. The primary difference of this alternative compared to the Enhanced Coordination and Maximum Operational Flexibility, which have similar maximum reduction volumes, is the level of reductions remain at 1.5 maf until Lake Mead falls to 1,025 feet, at which time the required reductions increase rapidly; The other similar alternatives use more gradually increasing reductions, thereby more proactively reducing the range of likely shortages under this Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average). Under the Average Flow Category (12.0-14.0 maf preceding 3-year average), water delivery reductions under the Enhanced Coordination Alternative range widely as the reduction curves span a wide step from no reductions to 1.5 maf of reductions as the combined effective storage of Lake Powell and Lake Mead exceeds 60 percent. In comparison, the Maximum Operational Flexibility Alternative has a linearly increasing reductions throughout the range of the combined seven-reservoir storage conditions, resulting in a comparatively consistent interquartile sizes throughout all preceding hydrologic conditions. In other words, the more continuous the shortage curves are in a policy design, the more uniform one can expect the shortage ranges to be within any hydrologic category, while policies that are designed with steps in shortage volumes result in wider possible variations of shortages once a storage condition nears the threshold of those steps. The upper limits of the interquartile ranges reflect the maximum shortages designed by the policies, but not those that would result from dead pool-related reductions.

All modeled results used to develop the conditional box plots for Mexico in **Figure N-4** are shown in **Table N-5**. The value within each cell represents the percent of Mexico's 1.5 maf allotment that would be subject to a water delivery reduction, and the shading represents instances where the maximum planned water delivery reduction occurs for each alternative. If a modeled scenario reaches the maximum water delivery reduction, then any additional water delivery reductions would occur as dead pool-related reductions and is not reflected in the magnitude of the cell values.

With maximum Lower Basin shortage volumes of 0.6 maf for the No Action Alternative (corresponding to a maximum 0.6 maf x 16.67 percent = 100.0 kaf reduction to Mexico) and 1.48 maf for the Basic Coordination Alternative (corresponding to an assumed maximum 1.48 maf x 16.67 percent = 247 kaf reduction to Mexico), the percent reduction numbers are comparatively low but the maximum reduction levels are reached in over half of the years (50th percentile) even within the Average Flow Category (12.0-14.0 maf). On the other extreme, under the Maximum Operational Flexibility Alternative, the shortage percentages are higher but with a maximum Lower Basin shortage of 4.0 maf (corresponding to an assumed maximum 4.0 maf x 16.67 percent = 100.0 kaf reduction to Mexico) this value is infrequently reached, i.e. only during the Critically Dry Flow Category (4.46-10.0 maf) and in less than 10 percent of traces and years modeled. In the Representative Preferred Alternative with a maximum Lower Basin shortage of 3.6 maf (corresponding to an assumed maximum of 3.6 maf x 16.67 percent = 400.0 kaf reduction to Mexico) this maximum reduction occurs across Dry through Moderately Wet hydrologic conditions (10.0-16.0 maf) but in less than 10 percent of all modeled futures. Only in Critically Dry hydrologic conditions (4.46-10.0 maf) do dead pool-related reductions occur in 25 percent of modeled futures.

Table N-5
Modeled water delivery reductions (as a percent of 1.5 maf allotment) to Mexico within each flow category

Alternative	Streamflow Group	Max	90th	75th	50th	25th	10th	Min
Cont. Current (max Mexico water delivery reduction = 275.0 kaf or ~18.3% of 1.5 maf)	Wet (> 16.0)	18.3	6.9	5.3	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	18.3	18.3	9.7	5.3	0.0	0.0	0.0
	Average (12.0-14.0)	18.3	18.3	18.3	10.3	5.3	0.0	0.0
	Dry (10.0-12.0)	18.3	18.3	18.3	18.3	10.3	2.7	0.0
	Critically Dry (4.46-10.0)	18.3	18.3	18.3	18.3	10.3	9.7	0.0
No Action (max Mexico water delivery reduction = 100.0 kaf or ~6.7% of 1.5 maf)	Wet (> 16.0)	6.7	6.7	6.7	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	6.7	6.7	6.7	6.7	0.0	0.0	0.0
	Average (12.0-14.0)	6.7	6.7	6.7	6.7	5.6	0.0	0.0
	Dry (10.0-12.0)	6.7	6.7	6.7	6.7	6.7	4.4	0.0
	Critically Dry (4.46-10.0)	6.7	6.7	6.7	6.7	6.7	5.6	0.0
Basic Coordination (max Mexico water delivery reduction = 247.0 kaf or ~16.4% of 1.5 maf)	Wet (> 16.0)	16.4	16.4	16.4	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	16.4	16.4	16.4	16.4	0.0	0.0	0.0
	Average (12.0-14.0)	16.4	16.4	16.4	16.4	11.7	0.0	0.0
	Dry (10.0-12.0)	16.4	16.4	16.4	16.4	16.4	8.7	0.0
	Critically Dry (4.46-10.0)	16.4	16.4	16.4	16.4	16.4	15.5	0.0
Enhanced Coordination (max Mexico water delivery reduction = 500.0 kaf or ~33.3% of 1.5 maf)	Wet (> 16.0)	24.4	0.0	0.0	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	33.3	19.9	17.0	0.0	0.0	0.0	0.0
	Average (12.0-14.0)	33.3	28.7	23.3	17.9	0.0	0.0	0.0
	Dry (10.0-12.0)	33.3	33.3	32.0	26.8	18.9	15.6	0.0
	Critically Dry (4.46-10.0)	33.3	33.3	33.3	33.3	28.1	20.7	0.0
Max Operational Flexibility (max Mexico water delivery reduction = 667.0 kaf or ~44.5% of 1.5 maf)	Wet (> 16.0)	21.4	11.4	5.7	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	29.2	19.4	15.1	9.7	2.8	0.0	0.0
	Average (12.0-14.0)	37.0	22.6	22.2	18.3	10.9	4.8	0.0
	Dry (10.0-12.0)	44.3	35.0	30.5	22.6	22.2	13.8	0.0
	Critically Dry (4.46-10.0)	44.5	44.3	40.2	34.3	27.3	22.2	4.1
Supply Driven LB Priority (max Mexico water delivery reduction = 350.0 kaf or ~23.3% of 1.5 maf)	Wet (> 16.0)	23.3	16.7	15.6	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	23.3	21.6	16.7	9.5	0.0	0.0	0.0
	Average (12.0-14.0)	23.3	23.3	20.4	16.7	2.1	0.0	0.0
	Dry (10.0-12.0)	23.3	23.3	23.3	19.5	16.7	1.7	0.0
	Critically Dry (4.46-10.0)	23.3	23.3	23.3	22.3	17.0	16.7	0.0
Supply Driven LB Pro Rata (max Mexico water delivery reduction = 350.0 kaf or ~23.3% of 1.5 maf)	Wet (> 16.0)	23.3	16.7	15.2	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	23.3	21.5	16.7	10.0	0.0	0.0	0.0
	Average (12.0-14.0)	23.3	23.3	20.4	16.7	2.7	0.0	0.0
	Dry (10.0-12.0)	23.3	23.3	23.3	19.7	16.7	2.2	0.0
	Critically Dry (4.46-10.0)	23.3	23.3	23.3	22.0	17.3	16.7	0.0

Alternative	Streamflow Group	Max	90th	75th	50th	25th	10th	Min
Representative Preferred (max Mexico water delivery reduction = 600.0 kaf or ~40.0% of 1.5 maf)	Wet (> 16.0)	33.0	16.7	2.6	0.0	0.0	0.0	0.0
	Mod. Wet (14.0-16.0)	40.0	16.7	16.7	2.3	0.0	0.0	0.0
	Average (12.0-14.0)	40.0	19.7	16.7	16.7	0.0	0.0	0.0
	Dry (10.0-12.0)	40.0	38.2	28.9	16.7	16.7	0.0	0.0
	Critically Dry (4.46-10.0)	40.0	40.0	40.0	26.5	16.7	16.0	0.0

Notes:
- Percentiles indicate the range of distribution with each category and correspond to the box plots in **Figure N-4**. Shading indicates conditions in which the maximum Lower Basin Shortage has been reached, thus the maximum planned water delivery reduction to Mexico has been reached. Numbers with shaded percentages do not include dead pool-related reductions, therefore total reductions to Mexico are likely greater than these percentages to maintain proportionality with total Lower Basin Shortages that do include dead pool-related reductions.
- The modeled annual delivery reductions to Mexico include assumptions that are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

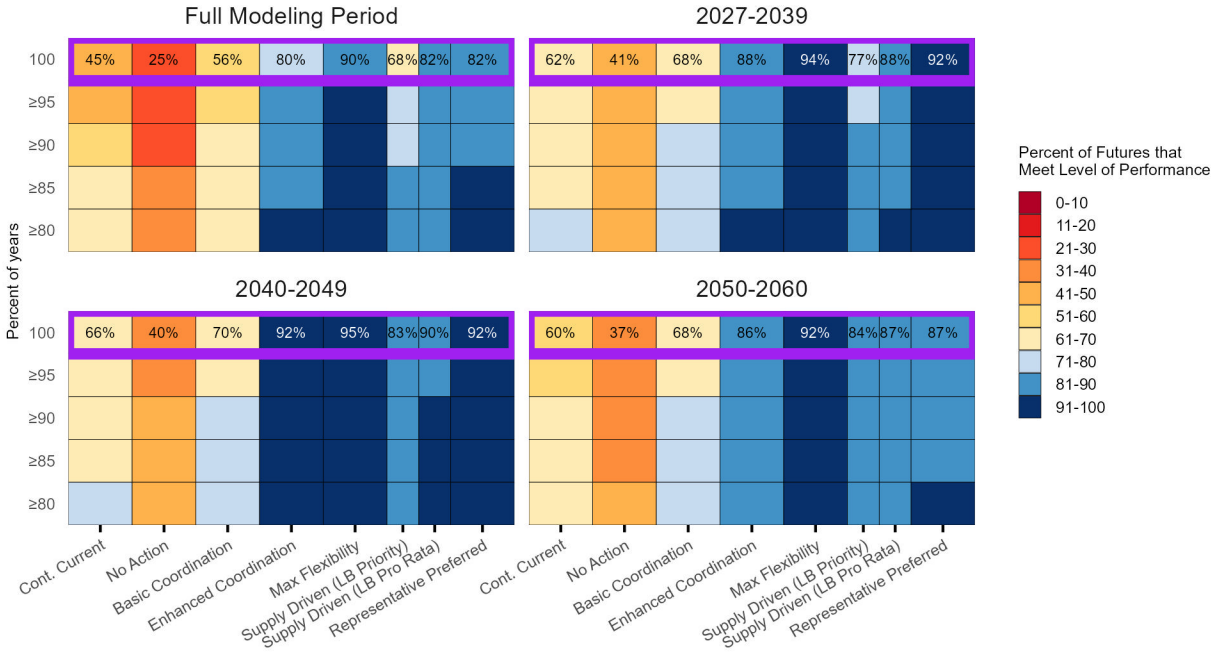
The cell values in **Table N-5** demonstrate how the magnitude of potential planned water delivery reductions generally increases based on the maximum reduction designed within the alternative, allowing a relative ranking of the alternatives from the lowest reductions in the No Action Alternative and increasing to the Maximum Operational Flexibility Alternative. The No Action Alternative shows the smallest numbers (up to 6.7 percent, corresponding to maximum reduction of 100.0 kaf for Mexico) which occur frequently, while the Maximum Operational Flexibility Alternative shows the largest numbers (up to 44.5 percent, corresponding to maximum reduction of 667.0 kaf for Mexico) but occurs infrequently across all modeled futures. The Representative Preferred Alternative has a maximum percent of Lower Basin water delivery reduction (up to 40.0 percent, corresponding to maximum reduction of 600.0 kaf for Mexico) falling between the Maximum Flexibility Alternative and Enhanced Coordination Alternative.

No Action	<	Basic Coord.	<	Current Cont. Strat.	<	Supply Driven Alternatives	<	Enhanced Coord.	<	Representative Preferred	<	Maximum Flexibility
Lowest Water Delivery Reductions												Highest Water Delivery Reductions

In contrast to the cell values, the extent of shading in **Table N-5** demonstrates the relative susceptibility of each alternative to reach its maximum shortage. If the maximum water delivery reductions are reached and the reservoirs continue to decline due to supply-demand imbalances, Mexico, along with users in the Lower Division States, would be subject to dead pool-related reductions as Lake Mead elevations decline. Only by keeping Lake Mead above dead pool can water releases assuredly be made to Mexico that are only subjected to planned reductions.

To support this finding, **Figure N-5** shows the ability of each alternative (columns) to avoid dead pool-related reductions at Lake Mead in the specified percent of years (rows) using the 400 futures analyzed in CRSS. The highlighted row in this robustness heatmap represents the percentage of futures that an alternative successfully avoids dead pool-related reductions in 100 percent of the years. The top left plot demonstrates the robustness across the 34-year modeled time horizon, while the other plots demonstrate the robustness of avoiding dead pool-related reductions in individual time periods of 2027-2039, 2040-2049, and 2050-2060.

Figure N-5
Lake Mead Dead Pool-Related Reductions Robustness Heatmap
Percent of futures in which dead pool-related reductions are avoided in the percent of years specified in each row



To support comparison among alternatives during the period most relevant to implementation of the Preferred Alternative, the heat maps focus on results from the first modeling period, which includes years 2027–2039. Considering this first modeling period, the Maximum Operational Flexibility Alternative keeps Mexico, along with all Lower Basin water users, from facing dead pool-related reductions in 94 percent of the 400 futures assessed, while the No Action Alternative avoids dead pool-related reductions in only 41 percent of futures. The CCS Comparative Baseline and Basic Coordination Alternative improve performance relative to the No Action Alternative by avoiding dead-pool related reductions in 62 and 68 percent of futures respectively (i.e. robustness scores), while the Supply Driven Alternative (LB Priority approach) reaches a 77 percent robustness score. The Enhanced Coordination Alternative and the Supply Driven Alternative (LB Pro Rata approach) achieve a robustness score near the level of the Maximum Operational Flexibility Alternative with 88 percent of the future hydrologic scenarios avoiding dead pool-related shortages. Finally, the Representative Preferred Alternative avoids dead pool-related reductions in 92 percent of future

hydrologic scenarios, reflecting a high level of protection from any reductions that would occur beyond those specified in this alternative. Given the focus on results on the first modeling period from 2027-2039, and the robustness scores in **Figure N-5**, a ranking of alternatives based on Mexico and Lower Division States' susceptibility to dead pool reductions is as follows.

Max. Flex.	<	Representative Preferred	<	Enhanced Coord.	=	Supply Driven Pro rata	<	Supply Driven Priority	<	Basic Coord.	<	Cont. Current	<	No Action
Lowest suscept-ability to dead pool reductions														Highest suscept-ability to dead pool reductions

The robustness analysis of future time periods in **Figure N-5** indicates somewhat different ranking orders for the Representative Preferred, Enhanced Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, but the Maximum Operational Flexibility always shows the highest level of robustness to protect against dead pool-related reductions while the No Action Alternative, CCS Comparative Baseline, and Basic Coordination Alternative results in the least robust alternatives with respect to dead pool-related reductions.

N.4.2 Issue 2: Quality of water delivered to Mexico

Water salinity of deliveries to Mexico are described in **TA 6**, Water Quality and summarized here, with a particular emphasis on salinity at Imperial Dam and NIB.

Due to natural and anthropogenic sources, high salinity in the Colorado River is an issue of concern for both the U.S. and Mexico and is actively managed. Minute 242 of the 1944 Water Treaty specifies a maximum annual differential of salinity between water that arrives at the Morelos Dam and that which arrives at the Imperial Dam. As described earlier, Reclamation meets this obligation through several coordinated actions. A portion of the water delivery to Mexico is met using pumped groundwater in the Yuma Area, which also helps to maintain water tables in the Yuma Area. While high-salinity groundwater can be bypassed through the MODE canal to route it around agricultural, municipal, and industrial systems in both the U.S. and Mexico, water bypassed through the MODE is not used to satisfy delivery obligations to Mexico; however, some quantity of pumped groundwater can be discharged into the river channel to help meet delivery obligations to Mexico. To ensure that water delivered at the NIB meets required salinity standards, Reclamation limits the volume of pumped groundwater discharged to the river to comply with the Minute 242 annual salinity differential of 115 ppm (+/- 30 ppm). The remainder of the pumped groundwater is either discharged to the MODE / Bypass Drain (in the case of pumped groundwater from the South Gila Valley) or is not pumped (in the case of water from the 242 Well Field that is delivered north through the 242 Pipeline and Yuma Mesa Conduit). To satisfy delivery obligations with Mexico, any volume that cannot be met from pumped groundwater is met from upstream releases of mainstream Colorado River water.

Relevant to the federal action addressed in this Final EIS is a comparative assessment of the long-term implications of the proposed alternatives on salinity levels at both the Imperial Dam and NIB. The impacts of the alternatives are provided as concentrations at the principal points of diversion at the Imperial Dam and NIB and are not intended to be used to determine salinity differential compliance as specified in Minute 242. To meet the salinity differential, Reclamation actively manages operations through the means described above at a smaller timescale than is required for this Final EIS; however, a sensitivity analysis was conducted to evaluate how varying the assumed volume of pumped groundwater (a key variable in managing deliveries and salinity pursuant to Minute 242) used to meet Mexico's delivery, within CRSS constraints, affects Lake Mead elevations, total Lower Basin shortages, and flows below Parker Dam (See **Box 1**).

Box 1: Sensitivity of Lake Mead to Varying the Assumed Volume of Pumped Groundwater Used to Meet Mexico's Delivery, within the Constraints of CRSS

Background

Reclamation primarily manages salinity levels at the NIB by varying the volume of pumped groundwater discharged to the Colorado River between Imperial Dam and the NIB and delivered to Mexico at the NIB to satisfy 1944 Water Treaty requirements. If pumped groundwater from the South Gila Valley (Drainage Pump Outlet Channels) cannot be delivered to the NIB due to Min 242 salinity limitations, it is discharged into the MODE where it is not charged to the 1944 Water Treaty. Similarly, if pumped groundwater from the 242 Well Field cannot be delivered to the NIB for reasons of salinity compliance, those wells are shut down (only those wells in the eastern portion of the 242 Well Field that discharge to the 242 Pipeline, Yuma Mesa Conduit, and ultimately the NIB). In CRSS, the only explicitly modeled pumped groundwater is assumed to be 25.0 kaf/year and broadly labeled as the 242 Well Field. When discharging pumped groundwater to the river would prohibit the U.S. from meeting the salinity differential of 115 ppm (+/- 30 ppm), the volume of pumped groundwater discharged into the Colorado River is reduced. Under this circumstance, to make up for the reduction of pumped groundwater discharged to the river, and to ensure delivery requirements to Mexico are maintained, upstream releases of mainstream Colorado River water are increased, which have a lower salinity than the pumped groundwater.

Sensitivity Analysis

With respect to salinity management, the highest level of impact on Lake Mead occurs when no additional pumped groundwater is introduced into the Colorado River between Imperial Dam and the NIB. This historically occurs intermittently throughout the year, therefore a conservative assumption with respect to the impacts on Lake Mead and subsequent Lower Basin shortages is to analyze the implications of eliminating the contributions of the 242 Well Field throughout the entire modeled period. Such an analysis indicates the impacts of reducing pumped groundwater by 25.0 kaf/year on Lake Mead.

Results

The implications of removing the contributions of pumped groundwater (labeled as the 242 Well Field) in the Representative Preferred Alternative are described here and shown in **Figure N-6**. Considering a year-by-year comparison across all 400 hydrologic futures, an overall average reduction in Lake Mead pool elevation of 0.93 feet occurs, with a median reduction of 0.96 feet.

This results in an increase of annual flows below Parker Dam by a mean (and median) of 25,000 af. As a result, there is a mean increase of 457 af in total Lower Basin shortages across all years and hydrologic futures. In the design of the Representative Preferred Alternative, the majority of modeled results for Lake Mead pool elevations occur where static shortages of zero, 1.5 maf or 3.6 maf result, hence there is no shortage increase whenever Lake Mead elevation falls within ranges from 1,145 to 1,125 feet and 1,025 to 975 feet (see **Chapter 2**, Description of Alternatives, **Figure 2-1**) and these threshold elevations are not crossed by the additional releases to reduce salinity. Considering the 5 categories of preceding 3-year hydrologic flow conditions, the median decrease in Lake Mead pool elevation ranges from 0.48 feet for the Wet hydrologic category (16-31.11 maf preceding 3-year average) to 2.38 feet for the Average hydrologic category (12.0-14.0 maf preceding 3-year average). This corresponds to median increases in annual flows below Parker Dam from 15,000 to 24,000 af respectively. When the preceding 3-year period has been Moderately Wet (14.0-16.0 maf) or Critically Dry (4.46-10.0 maf), Lake Mead is likely to be at elevations that fall along the narrow abrupt shortage changes (1,145 to 1,125 feet and 1,025 to 975 feet), resulting in median shortage increases of 92.0 kaf and 64.0 kaf within those respective categories.

Eliminating the contribution of the 242 Well Field and supplying the equivalent volume of water from Lake Mead releases only marginally improves the salinity at Imperial Dam but notably improves the salinity at the NIB by a mean (and median) of 19 mg/L (milligrams per liter; or ppm) across all years and hydrologic futures (**Figure N-7**). This difference in impact is due to two factors: 1) the relatively small proportional increase of inflows from Lake Mead to Imperial Dam (as a function of total flow at Imperial Dam) compared to the larger proportional increase of Colorado River flows delivered to NIB, as a function of the total NIB delivery, when eliminating the 242 Well Field; and 2) the replacement of higher saline inflows from the 242 Well Field, which only affects salinity at NIB and not Imperial Dam.

Figure N-6
Implications on Lake Mead Elevations, Lower Basin Shortages, and Flows Below Parker Dam when Removing Pumped Groundwater Contributions to Manage Salinity

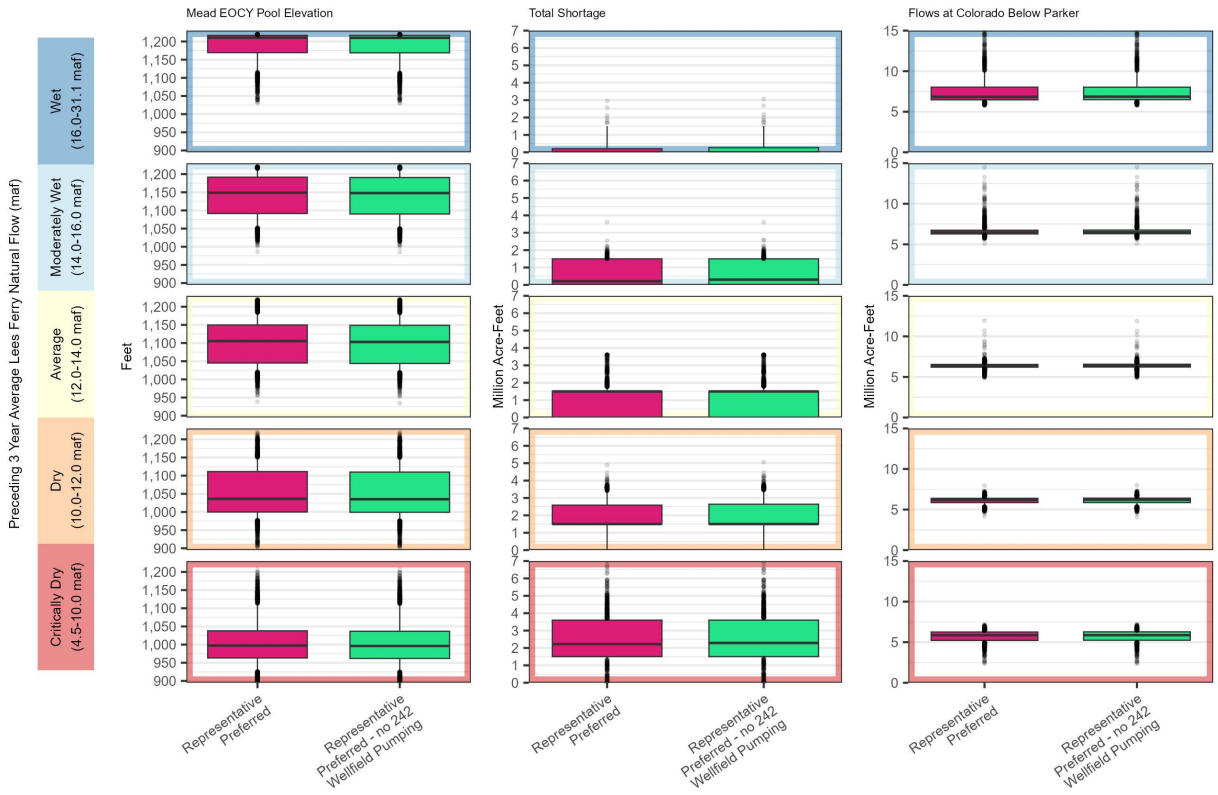
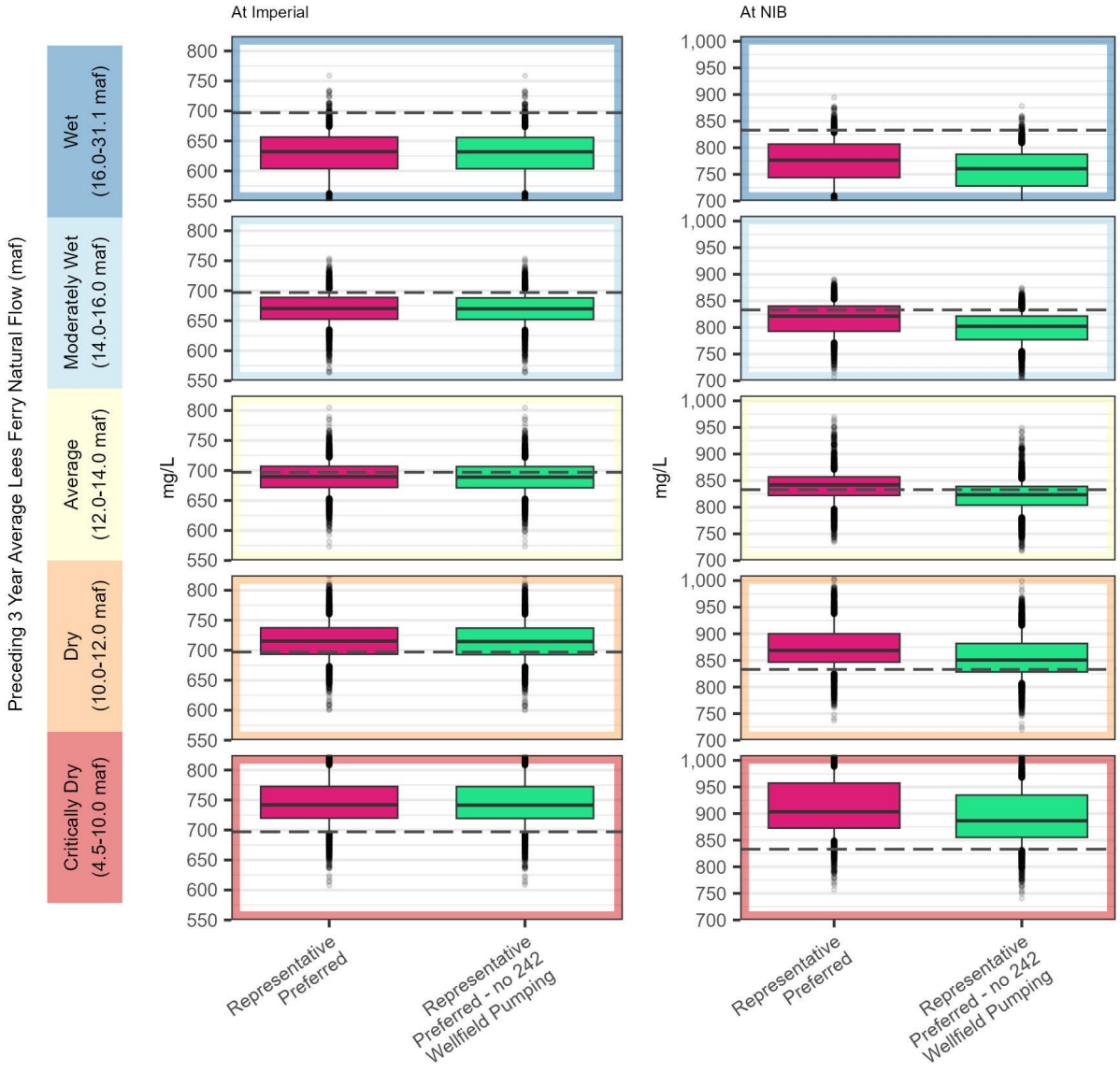


Figure N-7
Implications on Annual Flow-Weighted Average Salinity Concentrations when Removing Pumped Groundwater Contributions



N.4.2.1 Salinity ranges at Imperial Dam and NIB

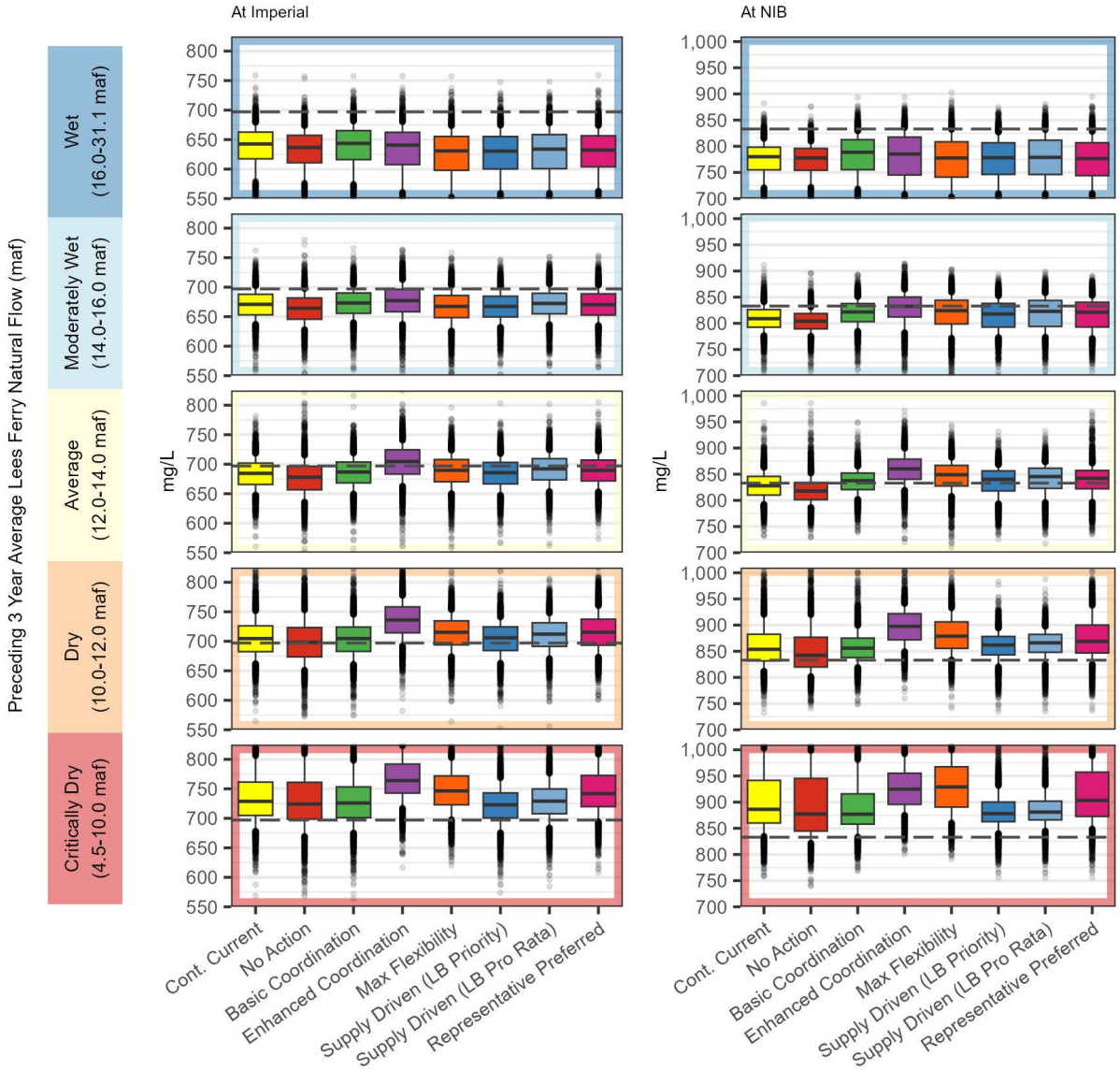
Average annual salinity ranges at Imperial Dam and NIB for the modeled alternatives are shown in **Figure N-8** using the same 5 preceding hydrologic flow categories to help visualize the different relative impacts throughout the 34-year period of analysis. While these graphics suggest similar impacts across the scenarios on an annual flow-weighted average basis, relative differences between the alternatives can be seen and are attributed primarily to the frequency of shortages and secondarily to the shortage distribution method used among water uses along the reaches below Lake Mead. For reference purposes, the flow-weighted average annual salinity from 2012 to 2024 is 697 mg/L at the Imperial Dam and 833 mg/L at NIB, shown as horizontal dotted lines in the conditional box plots. Salinity levels clearly increase under drier conditions compared to wetter conditions, with the interquartile ranges consistently below the reference lines in the Wet Category (16-31.1 maf preceding 3-year average) while the interquartile ranges of the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average) fall above these reference lines.

The magnitude of shortages has the effect of reducing releases and retaining more water in Lake Powell and Lake Mead in certain alternatives, so assuming the downstream mass loading of salt follows historical trends, this results in increasing salinity concentrations anywhere downstream of the reservoirs where flows are diminished[4]. At Imperial Dam, results from the Critically Dry Flow Category (4.46-10.0 maf preceding 3-year average) indicate that the highest median salinity values occur in the Enhanced Coordination Alternative, followed by the Maximum Operational Flexibility and Representative Preferred Alternatives, each of which have the highest maximum shortage policies 3.0, 4.0, and 3.6 maf/year respectively (**Figure N-8**). At NIB, the median salinity of the Maximum Operational Flexibility Alternative is slightly higher than the Enhanced Coordination Alternative, with the Representative Preferred Alternative resulting in the third highest salinity. However, the order of these three policies with respect to maximum shortages does not reflect the same order of resulting salinity levels. The second factor affecting salinity levels is the distribution and locations of shortages taken by users in the Lower Division States. Any reduction to water deliveries reduces the flows downstream of Lake Mead; however, shortages applied to users further downstream result in reduced overall flow volumes for longer stretches of the river, including at the point of diversion, as compared to the case when shortages are applied to users higher in the basin. As a conceptual example and strictly for the purpose of understanding this geographical aspect, reductions resulting in shortages to users only on the Central Arizona Project would reduce flows between Lake Mead and Lake Havasu but allow the same volume of water (and salinity dilution resulting from greater lateral inflow salinity concentrations) downstream of Lake Havasu and entering the All-American Canal at Imperial Dam as would occur without any shortages. However, reductions of the same magnitude taken only from the Imperial Irrigation District would result in lower flows from Lake Mead to the Imperial Dam resulting in higher salinity values into the All-American Canal (and less-so at the Morelos Dam) due to salinity sources introduced between Lake Havasu and the Imperial Dam. When considering these spatial relationships of the users alongside the priority system with more junior users upstream (i.e., Central Arizona Project) and more senior users downstream (i.e. Imperial Irrigation District), an alternative with priority distribution would tend to result in lower salinity levels at Imperial Dam while a pro rata distribution would result in

[4] In the case of NIB, operational modifications on a smaller timescale by Reclamation's Yuma Area Office can be made to ensure that the Minute 242 salinity differential is met.

higher salinity levels at Imperial Dam. This result is apparent in the Supply Driven Alternative (LB Pro Rata approach) resulting in higher salinity levels at Imperial Dam compared to the Supply Driven Alternative (LB Priority approach). Even more pronounced is the higher salinity levels at Imperial Dam resulting from the Enhanced Coordination Alternative, which uses a basin-wide pro rata shortage allocation, relative to the Maximum Operational Flexibility and Representative Preferred Alternatives, both of which primarily use priority-based shortage allocations.

Figure N-8
Conditional Box Plots of Annual Flow-Weighted Average Salinity Concentrations at Imperial Dam and at the Northerly International Boundary (NIB). Dashed horizontal lines represent the flow-weighted average annual salinity from 2012 to 2024 (697 mg/L at Imperial Dam and 833 mg/L at NIB)



Differences in salinity levels using priority vs. pro rata alternatives are not apparent at NIB because of two reasons. First, both distribution methods assume that a 16.67 percent water delivery reduction to Mexico is applied from any shortage that occurs and is therefore not subject to the choice of distribution method. In other words, the volume of water that flows past the Imperial Dam and reaches the NIB is the same regardless of the decision of priority vs. pro rata among users in the Lower Division States. Second, salt loading introduced below Imperial Dam only affects salinity levels at Morelos Dam and are not affected by distribution methods upstream in the USA. The lack of effect of distribution method on salinity at NIB reveals that salinity sources between Imperial and NIB dominate the effects of varying salinity concentrations further upstream.

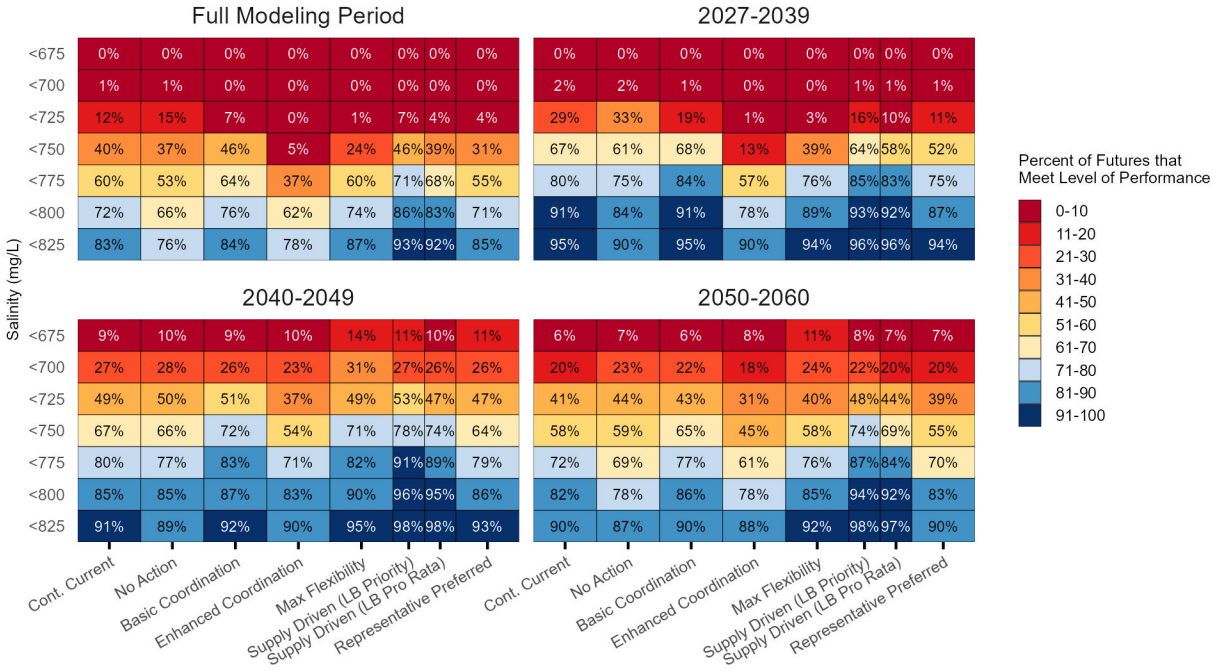
N.4.2.2 Number of traces that average annual salinity at Imperial Dam and NIB exceed tolerances[5]

The differences in policies over various levels of salinity are also shown in **Figure N-9** for Imperial Dam and **Figure N-10** for NIB. These heatmaps demonstrate the percent of futures that meet a level of performance as defined by the maximum salinity levels on the y-axis, with the most difficult criteria to achieve being a lower salinity concentration (top row) and the easiest criteria to achieve being a larger salinity number (bottom row). The heatmaps are provided considering the full modeled period (2027-2060) as well as three incremental periods (2027-2039, 2040-2049, and 2050-2060), allowing an understanding of the ability to stay below thresholds over time. A range of average annual salinity thresholds are provided at each location to accommodate the impacts on different uses.

As described earlier, the flow-weighted average annual salinity at the Imperial Dam from 2012 to 2024 is 697 mg/L. To evaluate alternatives with an approximation of this criterion using **Figure N-9**, one can see that all alternatives, including the Representative Preferred Alternative, are rarely able to maintain salinities below 700 mg/L when considering the- entire modeling time horizon of 2027 to 2060, meaning the salinity exceeds this threshold at some point under almost every alternative during this modeled time range. To support comparison among alternatives during the period most relevant to implementation of the Preferred Alternative, we initially focus on results from the first modeling period, which includes years 2027–2039. During this period, **Figure N-9**, also shows the inability to stay below the salinity threshold of 700 mg/L. This first decade is heavily influenced by the current low reservoir conditions and high likelihood of shortages, resulting in reduced releases from Lake Mead.

[5] The salinity analysis provided by CRSS is on a monthly basis and on a coarse spatial resolution and therefore does not capture the operational options that Reclamation has to manage salinity to meet the differential as described in Minute 242. The value of this analysis is also not in the absolute numbers which are an aggregation of multiple hydrologic scenarios and across time, but instead to compare the alternatives considered in this EIS based on the relative implications for salinity levels at key locations.

Figure N-9
Salinity at Imperial: Robustness
Percent of futures in which the concentration is below the specified value in every year

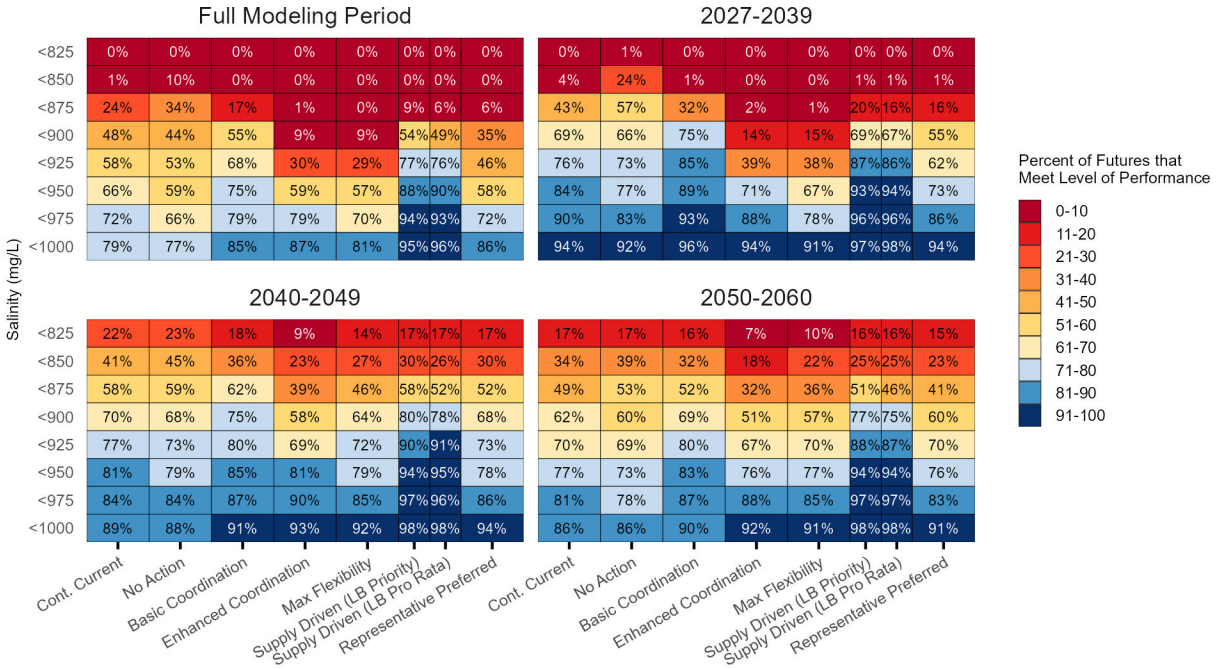


However, when looking at time ranges into the future when initial reservoir conditions are less influential on the results, the No Action Alternative produces results that stay below 700 mg/L in 28 percent of the futures in the 2040-2049 time range, and 23 percent in the 2050-2060 time range. With results quite similar to the No Action Alternative, the Maximum Operational Flexibility Alternative has the highest number of futures that stay below 700 mg/L with 31 percent of futures from 2040-2049 and 24 percent of futures from 2050-2060. The narrow range of percentages among these vastly different alternatives indicates a relative insensitivity of maximum shortages to stay below this particular salinity threshold. The alternative with the least number of futures that stay below 700 mg/L is the Enhanced Coordination Alternative, which uses a basin-wide pro rata shortage distribution method, resulting in 23 percent and 18 percent of futures staying below this threshold over the 2040-2049 and 2050-2060 time ranges respectively. This indicates that the distribution method has a more profound impact on salinity than the overall levels of shortage at the 700 mg/L threshold at Imperial Dam, however this tendency does not hold true across all salinity thresholds with the maximum shortage having an increasing impact under less stringent salinity criteria. The influence of the distribution method is also demonstrated by observing the two approaches of the Supply Driven Alternative and noting the LB Pro Rata approach consistently scores less than the LB Priority approach.

With respect to the Representative Preferred Alternative relative to the No Action Alternative, and particularly during the first decade of the analysis (2027-2039), widening the range of salinity thresholds reveals that a reduction in robustness from 33 percent to 11 can be seen when aiming to

stay below 725 mg/L and from 61 percent to 52 percent when aiming to stay below 750 mg/L. The reductions are significantly less than the changes resulting from the Enhanced Coordination and Maximum Operational Flexibility Alternatives which effectively never stay below these salinity thresholds during this initial decade. **Figure N-10** shows the relative impacts of the modeled alternatives on salinity at NIB. As described earlier, the flow-weighted average annual salinity at the NIB from 2012 to 2024 is 833 mg/L. Although this specific value is not listed among the y-axis of **Figure N-10**, the figure reveals that the ability to avoid salinity levels that exceed this concentration are rare in the first decade of analysis (2027-2039) but increases in subsequent decades (2040-2049 and 2050-2060). Overall, avoiding critical salinity levels is more likely in the No Action Alternative, CCS Comparative Baseline, and Basic Coordination. For example, staying under an 850 mg/L threshold occurs in 24 percent of the futures under the No Action Alternative in 2027-2039, but staying below this threshold is nearly impossible in the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), or Representative Preferred Alternatives, indicating a more notable impact of high maximum policy shortages on the salinity at NIB compared to salinity at Imperial Dam. Furthermore, exceeding salinity thresholds at NIB is not significantly affected by the choice of shortage distribution method, which can be seen with the nearly equal percent of futures between the LB Priority and LB Pro Rata approaches of the Supply Driven Alternative. This lack of influence of the distribution method at NIB compared to Imperial Dam is again explained by the dominant role of additional salinity introduced between the two locations.

Figure N-10
Salinity at the NIB: Robustness
Percent of futures in which the concentration is below the specified value in every year



N.4.3 Issue 3: Flows below Morelos Dam

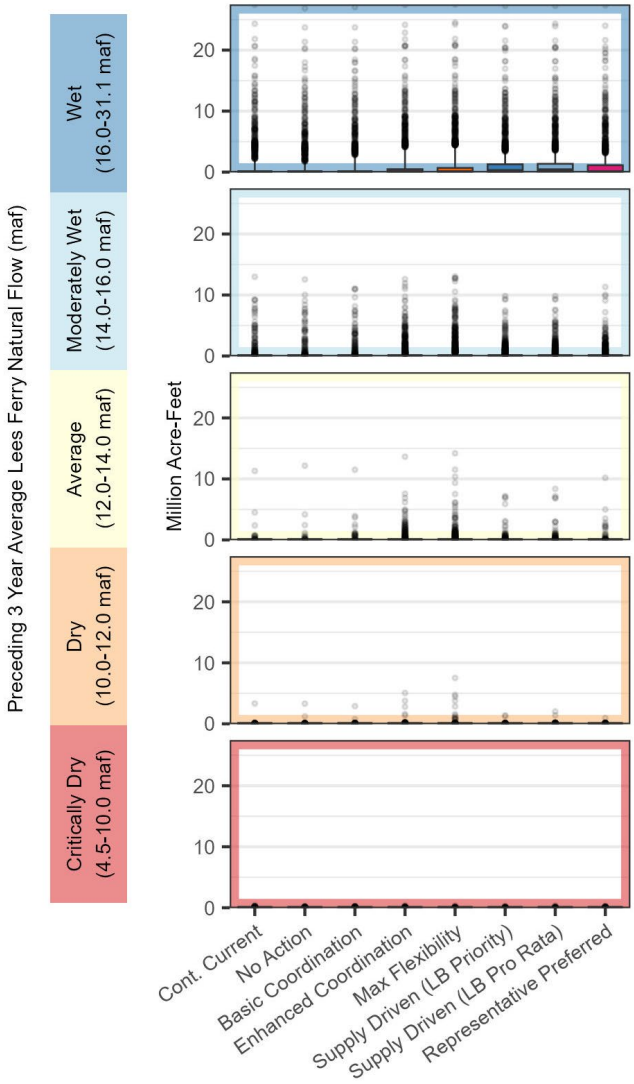
As shown previously in **Figure N-2**, flows in the Limitrophe were historically significant in the 1980s during flood control years; however, in recent years these flows have been limited to water passing Morelos Dam in excess of Mexico's scheduled delivery due to flood control operations at Hoover Dam, releases from Hoover Dam that cannot be used due to local circumstances such as unexpected rainfall, seepage from Morelos Dam, flows from the Gila River, irrigation return flows, groundwater inflow, or water released in 2014 specifically for the purpose of environmental restoration related to Minute 319. **Figure N-11** shows the volumes of water released from Morelos Dam under the different alternatives analyzed and categorized by the same preceding 3-year Lees Ferry natural flows used in previous analyses. The implications of the alternatives for the Limitrophe differ primarily due to changes in the frequency and magnitude of possible future flood control releases. As Lake Powell and Lake Mead are maintained in higher elevations such as in the Maximum Operational Flexibility Alternative, there is an increased likelihood of spills causing such flood control releases from Lake Mead. This difference, however, is only observable in limited ranges of hydrologic conditions from Dry to Moderately Wet preceding 3-year averages.

Most notable, under the Average, Dry, and Critically Dry hydrologic categories (below 14.0 maf preceding 3-year average) flows below Morelos Dam into the Limitrophe occur in less than 10 percent of the hydrologic futures and therefore can be considered infrequent and incidental. Even in the Moderately Wet Flow Category (14.0-16.0 maf preceding 3-year average), flows in the limitrophe occur in the Enhanced Coordination, Maximum Operational Flexibility, and both Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) in just over 10 percent of the modeled futures. In the Wet Flow Category (16.0-31.1 maf preceding 3-year average), the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results in some flows in the Limitrophe at the median (50 percent of modeled futures), but in the Representative Preferred Alternative, flows occur in only 25 percent of modeled futures.

Although infrequent, in all hydrologic categories except for the Critically Dry Flow Category (4.46-10.0 maf), there is always a possibility of short-duration large volume flows in the Limitrophe. These are the result of exceptionally high flows that could occur in some of the hydrologic futures considered in the modeling analysis.

The modeled flows in **Figure N-11** are exclusively the result of flood control releases. Future water use could also occur due to restoration efforts in the Limitrophe. Although habitat conditions are severely deteriorated from natural conditions, previous restoration efforts have resulted in positive responses in sites such as Hunters Hole in the U.S. and Miguel Aleman in Mexico. These sites are irrigated through pumped groundwater or releases made from Mexico's canal system and not reliant on flows immediately below Morelos Dam. A third site, initiated by the Cocopah Indian Tribe, will add a further 400 acres of native habitat and will be supplied from a conveyance pipe delivering a portion of the Tribe's unused rights from a nearby irrigation canal. In the modeling of alternatives for this EIS, releases made for environmental restoration sites are assumed to be diverted by Mexico at Morelos Dam and re-released into the Colorado River in Mexico after traveling through Mexico's canal infrastructure, therefore, are not reflected in **Figure N-11**. These releases are explicitly and exclusively included in the Maximum Operational Flexibility Alternative.

Figure N-11
Calendar Year Total Annual Flow Volume Released Below Morelos Dam



Implications of the modeled alternatives on riparian vegetation and habitat conditions in the Limitrophe reach are not explicitly modeled for comparison, but one can surmise from the Minute 319 environmental pulse flow in 2014 that increased frequency of flows passing below Morelos Dam resulting from flood control releases from Lake Mead is beneficial for these conditions and reduced likelihood of flood flows and continued groundwater declines will cause further vegetation deterioration in this region. The intermittent nature of future natural flooding events reaching the Limitrophe suggests that the Maximum Operational Flexibility Alternative, which provides for storing of water and periodic releases for habitat restoration, is the only alternative that is likely to have beneficial implications for vegetation and habitat conditions in this region.

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Appendix O

Analysis of Lake Powell Infrastructure Protection Releases

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APPENDIX O. ANALYSIS OF LAKE POWELL INFRASTRUCTURE PROTECTION RELEASES O-1

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CCS	Continued Current Strategies
EIS	environmental impact statement
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
PIP	Powell infrastructure protection
UIU	Upper Initial Unit

Appendix O. Analysis of Lake Powell Infrastructure Protection Releases

O.1 Lake Powell Infrastructure Protection Release Analysis

The Final Environmental Impact Statement (EIS) includes alternatives that assume additional releases from the Colorado River Storage Project Upper Initial Units (UIUs; Flaming Gorge, Blue Mesa, and Navajo Reservoirs) to protect infrastructure at Lake Powell. Operations at these units specifically contemplated in the Final EIS alternatives are intended to remain within the scope of the existing Records of Decision. This appendix analyzes these modeled releases – referred to as Powell infrastructure protection (PIP) releases – across alternatives. The PIP release modeling assumptions are simplifications of the actual PIP process, which, like the Drought Response Operations Agreement, involves collaborative decision-making among stakeholder workgroups and includes subjective judgments that cannot be captured in a model. The modeled PIP releases represent a potential range of releases and do not necessarily reflect the views of all stakeholders. Actual releases may be lower, higher, or may not occur. The modeling assumptions regarding operation of the UIUs presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes as stated in the 1956 Colorado River Storage Project Act. These modeling assumptions are intended solely for National Environmental Policy Act analysis and do not reflect a position by Reclamation on operations that might be implemented under a PIP collaborative process.

The Continued Current Strategies (CCS) Comparative Baseline, Basic Coordination Alternative, Supply Driven (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) Alternative, and Representative Preferred Alternative include modeled PIP releases, which are triggered when Lake Powell is projected to decline, or physically declines, below elevation 3,525 feet. The CCS Comparative Baseline and the Basic Coordination and Representative Preferred Alternatives assume additional releases from Flaming Gorge, Blue Mesa, and Navajo Reservoirs, while the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative assumes additional releases only from Flaming Gorge Reservoir. Each UIU's operations are adjusted within their Records of Decision as noted in **Appendix A**, CRSS Model Documentation, **Section A.5.11**. Additionally, PIP releases in the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative are limited to 500 thousand acre-feet (kaf) annually, while the CCS Comparative Baseline, the Basic Coordination and Representative Preferred Alternatives do not have constraints on annual releases. The Lower Colorado River Basin (Lower Basin) shortage distribution method does not impact Upper Colorado River Basin operations for the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative, as the Lake Powell operations are independent from Lower Basin operations. While the results for both Lower Basin shortage distribution methods are

included, the results included in this appendix are identical and will therefore not be differentiated in the discussion. Details on modeling assumptions are in **Appendix A**, CRSS Model Documentation, **Section A.5.11**. The following sections compare the responses of individual and total annual PIP release volumes and frequency under different hydrologic conditions. Results are presented using conditional plots, which separate results based on five flow categories (see **Chapter 3.2.6** for additional details on conditional plots).

O.1.1 PIP Release Volumes

PIP release volumes shown in **Figure O-1** are estimates of the additional annual volumes released from each UIU and the total of all three UIUs. Each reservoir has different operating years and monthly targets that are used to estimate the additional releases. During years when PIP releases are triggered due to Lake Powell's projected or actual pool elevation, the following calculations are used to estimate annual additional release volumes:

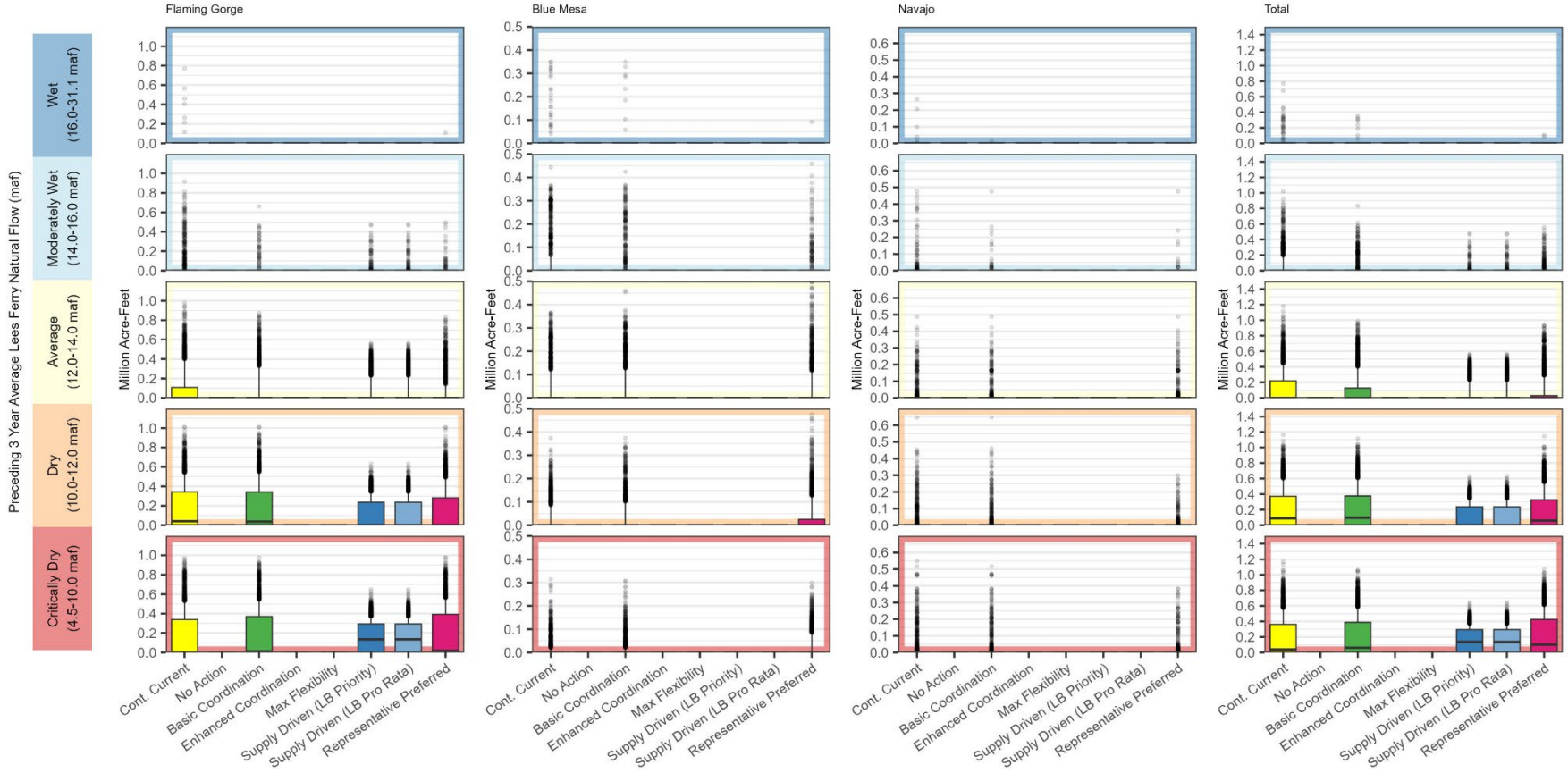
- Flaming Gorge: previous May 1 (April 30 in Colorado River Simulation System) storage minus current May 1 storage
- Blue Mesa: previous December 31 storage minus current December 31 storage
- Navajo: sum of water year additional releases

Even though the UIUs operate on different annual scales, their annual volumes are aggregated to compute a total annual volume of estimated PIP water released, since additional releases from Flaming Gorge and Blue Mesa cannot be determined each month in Colorado River Simulation System.

Figure O-1 shows PIP release volumes across all years (2027-2060) of the simulation. If there is no PIP release in a year, the data remains in the plot as zero. Each boxplot in the figure illustrates the distribution of modeled results, where the bold center line represents the median value, the top and bottom of each box shows the interquartile range, which captures the 25th to 75th percentile, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives are zero for all flow categories and all percentiles because PIP releases are not included in those alternatives.

Figure O-1 illustrates that there are limited PIP releases in the Average Flow Category. Volumes released from UIUs are zero at the median. When aggregated to total volumes, the upper quartile of the CCS Comparative Baseline is 220 kaf, the Basic Coordination Alternative is 130 kaf, and the Representative Preferred Alternative is 30 kaf, while the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative remains at zero.

Figure O-1
Response of PIP Release Volumes by Reservoir Across Alternatives

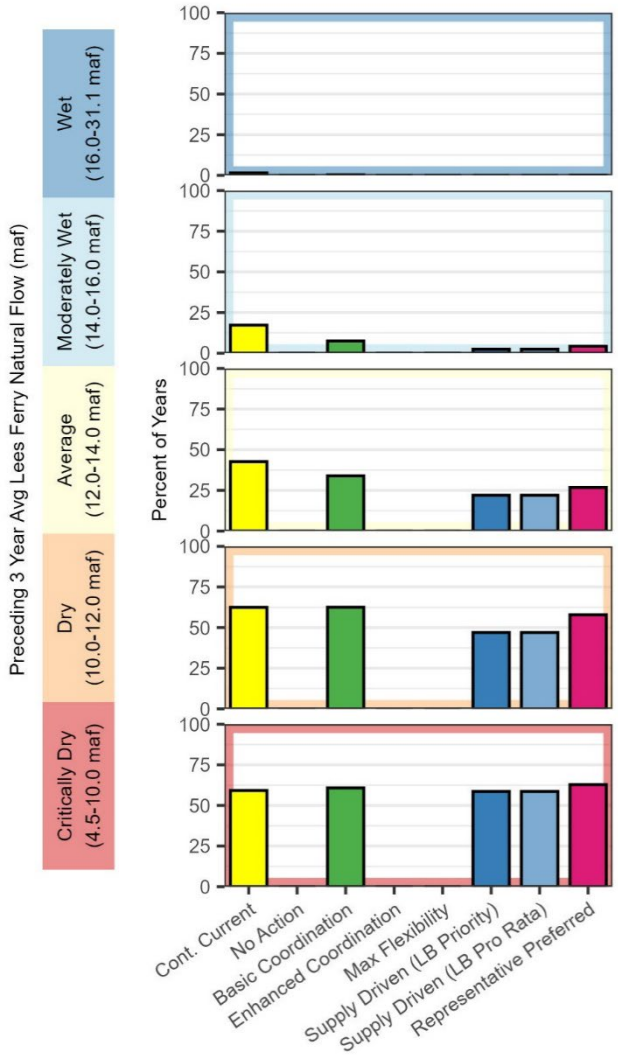


As hydrologic conditions become drier, PIP releases increase in volume. In the Critically Dry Flow Category, median PIP releases are greater than zero in all scenarios that include PIP releases; the total PIP releases are 38 kaf, 61 kaf, 100 kaf, and 136 kaf, for the CCS Comparative Baseline, Basic Coordination Alternative, Representative Preferred Alternative, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative, respectively. Most of the PIP releases come from Flaming Gorge, which has the largest storage of any of the UIUs. For the CCS Comparative Baseline and the Representative Preferred and Basic Coordination Alternatives in the Critically Dry Flow Category, annual total releases can be as large as 1.2 million acre-feet, but 90 percent of the futures release 0.6 million acre-feet or less. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative has releases up to 650 kaf, but 90 percent of the releases are 380 kaf or less. Under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative, the maximum PIP release at Flaming Gorge is specified to be 500 kaf; however, there are a few instances where Flaming Gorge is modeled to release more than 500 kaf due to monthly operational constraints.

O.1.2 PIP Release Frequency

PIP release frequency across all years (2027-2060) of the simulation by hydrologic condition is shown in **Figure O-2**. Each bar in the figure reports the percent of years with PIP releases in each flow category. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives are zero for all flow categories because PIP releases are not included in those alternatives. In the Average Flow Category, PIP releases occur more frequently under the CCS Comparative Baseline and the Basic Coordination Alternative at 43 percent and 34 percent of years, respectively, compared to the Representative Preferred and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives at 27 and 22 percent of years, respectively. The frequency of PIP releases is greater in the Dry Flow Category than the Average Flow Category across all scenarios where PIP releases are modeled. In the Critically Dry Flow Category, the percent of years with PIP releases decreases slightly in the Dry Flow Category under the CCS Comparative Baseline (59 versus 62 percent of years) and the Basic Coordination Alternative (61 versus 62 percent of years). Under the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives, PIP releases are greatest in the Critically Dry Flow Category, occurring in 59 and 63 percent of years, respectively.

Figure O-2
Percent of Years with PIP Releases Across Alternatives



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Appendix P

Appendix P. Tribal Consultation and Coordination Efforts

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
Basin	Colorado River Basin
CAP	Central Arizona Project
EIS	Environmental Impact Statement
NEPA	National Environmental Policy Act
NOI	Notice of Intent
Reclamation	Bureau of Reclamation

Appendix P. Tribal Consultation and Coordination Efforts

For purposes of this National Environmental Policy Act (NEPA) process, the Bureau of Reclamation (Reclamation) is consulting and coordinating with Basin Tribes who have entitlements to or contracts for Colorado River water and those that may be affected by or have interests in the proposed federal action.

P.1 Summary of Tribal Consultation and Coordination

There are many federally recognized tribes with entitlements to or contracts for Colorado River water, or who may be affected by or have interests in the proposed federal action. There are 30 federally recognized tribes within the geographic Colorado River Basin (Basin). Reclamation consults regularly with these tribes regarding Colorado River issues. These tribes are listed in **Table P-1** and shown on **Map P-1**.

Table P-1
Basin Tribes

- Ak-Chin Indian Community
- Chemehuevi Indian Tribe
- Cocopah Indian Tribe
- Colorado River Indian Tribes
- Fort McDowell Yavapai Nation
- Fort Mojave Indian Tribe
- Gila River Indian Community
- Havasupai Tribe
- Hopi Tribe
- Hualapai Indian Tribe
- Jicarilla Apache Nation
- Kaibab Band of Paiute Indians
- Las Vegas Tribe of Paiute Indians
- Moapa Band of Paiute Indians
- Navajo Nation
- Paiute Indian Tribe of Utah
- Pascua Yaqui Tribe
- Quechan Indian Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Tribe
- San Juan Southern Paiute
- Southern Ute Indian Tribe
- Tohono O'odham Nation
- Tonto Apache Tribe
- Ute Indian Tribe of the Uintah and Ouray Reservation
- Ute Mountain Ute Tribe
- White Mountain Apache Tribe
- Yavapai-Apache Nation
- Yavapai-Prescott Indian Tribe
- Zuni Tribe

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RECLAMATION

Map P-1
Tribes and Reservations within the Colorado River Basin



The Ten Tribes Partnership is a coalition of 10 federally recognized tribes with rights and unresolved claims to Colorado River water. The partnership was created in 1992 and has an ongoing consultation relationship with Reclamation. Federally recognized tribes of the Ten Tribes Partnership are listed in **Table P-2**.

Table P-2
Ten Tribes Partnership Tribes

- Ute Mountain Ute Tribe
- Southern Ute Indian Tribe
- Ute Indian Tribe of the Uintah and Ouray Reservation
- Jicarilla Apache Nation
- Navajo Nation
- Fort Mojave Indian Tribe
- Colorado River Indian Tribes
- Chemehuevi Indian Tribe
- Quechan Indian Tribe
- Cocopah Indian Tribe

Of the 22 federally recognized tribes in Arizona, 14 have fully resolved, adjudicated rights, or partially resolved rights to water from the Colorado River. A significant portion of that water is provided through the Central Arizona Project (CAP). Reclamation has a long-standing and ongoing consultation relationship with tribes receiving Colorado River water through the CAP. **Table P-3** lists CAP Tribes.

Table P-3
CAP Tribes

- Ak-Chin Indian Community
- Fort McDowell Yavapai Nation
- Gila River Indian Community
- Hualapai Tribe
- Pascua Yaqui Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Tribe
- Tohono O'odham Nation
- Tonto Apache Tribe
- White Mountain Apache Tribe
- Yavapai-Apache Nation
- Yavapai-Prescott Tribe

Reclamation consults not only with tribes who hold water rights or are located within the geographic boundary of the Basin, but also with tribes who may be affected or have interests in actions on the Colorado River. **Table P-4** lists the 43 federally recognized tribes with whom Reclamation consults on issues regarding the Colorado River.

Table P-4
Tribes Consulted on Colorado River Issues

- Ak-Chin Indian Community
- Chemehuevi Indian Tribe
- Cocopah Tribe of Arizona
- Colorado River Indian Tribes
- Fort McDowell Yavapai Nation
- Fort Mojave Indian Tribe
- Gila River Indian Community
- Havasupai Indian Tribe
- Hopi Tribe
- Hualapai Indian Tribe
- Jicarilla Apache Nation
- Kaibab Band of Paiute Indians
- Las Vegas Tribe of Paiute Indians
- Moapa Band of Paiute Indians
- Navajo Nation
- Paiute Indian Tribe of Utah
- Pascua Yaqui Tribe
- Pueblo of Acoma
- Pueblo of Cochiti
- Pueblo of Jemez
- Pueblo of Laguna
- Pueblo of Nambé
- Pueblo of Pojoaque
- Pueblo of San Felipe
- Pueblo of San Juan
- Pueblo of Sandia
- Pueblo of Santa Ana
- Pueblo of Santa Clara
- Pueblo of Tesuque
- Pueblo of Zia
- Quechan Indian Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Tribe
- San Juan Southern Paiute Tribe
- Southern Ute Indian Tribe
- Tohono O'odham Nation
- Tonto Apache Tribe
- Ute Indian Tribe of the Uintah and Ouray Reservation
- Ute Mountain Ute Tribe
- White Mountain Apache Tribe
- Yavapai-Apache Nation
- Yavapai-Prescott Tribe
- Zuni Tribe

P.2 Tribal Consultation Efforts

Reclamation has engaged regularly with the tribes since the publication of the notice of intent (NOI) to prepare the Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead Environmental Impact Statement (EIS) on June 16, 2023. **Table P-5** provides a summary of those tribal consultation and coordination efforts conducted by Reclamation between publication of the NOI and July 1, 2026.

On June 24, 2022, Reclamation published a Federal Register Notice to conduct a public "pre-scoping" effort requesting public input on the process and substantiative elements for post-2026 operations prior to the anticipated initiation of the formal NEPA in 2023. In response to the public comment period that ran through September 1, 2022, Reclamation received 11 letters from individual tribes and two group letters from Basin Tribes.

Reclamation formally commenced post-2026 tribal consultation on June 12, 2023, with a letter to all 30 Basin Tribes announcing the posting of the NOI in the Federal Register and the start of a scoping comment period. In response to this scoping comment period, Reclamation received 16 letters from individual Basin Tribes. The results of the scoping period were compiled in the Scoping

Summary Report and shared with the Basin Tribes. During the scoping period, Reclamation conducted seven individual government-to-government consultations with Basin Tribes and hosted fifteen group tribal meetings across the Basin.

On January 18, 2024, Reclamation sent a consultation letter to the 30 Basin Tribes initiating the alternatives development phase of the process. The goal of the alternatives development phase was to provide a reasonable and broad range of alternatives for managing the Colorado River system and its resources through consultation and collaboration with a broad range of stakeholders. During the alternatives development phase, Reclamation conducted 16 individual government-to-government consultations with Basin Tribes and hosted 64 group tribal meetings across the Basin. In addition, a group of Basin Tribes informed Reclamation's development of the Enhanced Coordination Alternative through participation in meetings throughout 2024 and 2025 to discuss proposed management strategies and review modeling results.

On January 15, 2026, Reclamation sent a letter to the 30 Basin Tribes announcing the publication of the Draft EIS and initiating formal consultation. In connection with the release of the Draft EIS, Reclamation hosted a series of technical meetings with tribes to provide an overview of the document and set up additional consultations. During the Draft EIS public comment period, Reclamation participated in individual government-to-government consultations with 20 of the 30 Basin Tribes and received 23 tribal comment letters. Following the initial Draft EIS consultation, Reclamation continued to meet regularly with tribes during the development of the preferred alternative and Water Year 27/28 Operations plans. Between March 19 and July 1, 2026, Reclamation hosted 10 group tribal technical meetings and 16 government-to-government consultations with the Basin Tribes.

Throughout the Post-2026 NEPA process, Reclamation and the Basin Tribes committed to a robust communication and consultation plan that incorporated tribal priorities and comments into the process. Reclamation and tribes engaged each other through monthly information calls, tribal technical workgroups, and government-to-government consultations to ensure that tribes remained informed on the developing process and provided meaningful contributions to the final NEPA analysis and operations plan. At the conclusion of the NEPA process and signing of the Record of Decision, Reclamation will continue to consult with the Basin Tribes on operational decisions related to the 10-year decision framework.

Table P-5
Summary of Tribal Consultation Efforts

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
6/12/2023	Tribal Letter: Upcoming Notice of Intent to Prepare an EIS for Development of Post-2026 Colorado River Operations	Notification of NOI and scoping comment period	Letter sent to tribal leaders of the 30 Basin Tribes
6/13/2023	Meeting with Gila River Indian Community	Virtual meeting	Gila River Indian Community

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
6/14/2023	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
6/15/2023	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for tribes throughout the Basin
6/15/2023	Southern Ute Indian Tribe Visit	Southern Ute invited Upper Colorado Basin leadership to meet with the council to discuss the Colorado River, tribal water infrastructure needs, and tour projects on the reservation.	Southern Ute Indian Tribe
7/20/2023	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for tribes throughout the Basin
8/8/2023	Meeting with Gila River Indian Community	Hybrid meeting; in person in Washington, DC	Gila River Indian Community
8/9/2023	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
8/11/2023	Inter-Tribal Council of Arizona	Tribal Leaders' Water Policy Council	Leaders from 21 tribes in Arizona
8/24/2023	Basin Tribal Information Exchange	Monthly meeting	Tribal leaders and representatives for tribes throughout the Basin
8/29/2023	Jicarilla Apache Nation Visit	Jicarilla Apache invited Upper Colorado Basin leadership to meet with the council to discuss the Colorado River and tribal concerns	Jicarilla Apache Nation
8/30/2023	Ute Mountain Ute Tribe Visit	Ute Mountain Ute invited Upper Colorado Basin leadership to meet with the council to discuss the Colorado River, tribal water infrastructure needs, and tour projects on the reservation.	Ute Mountain Ute Tribe
9/5/2023	Southern Ute Indian Tribe	Government-to-government consultation	Southern Ute Indian Tribe
9/19/2023	Federal-Tribes-States Legal/Technical Group Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
9/21/2023	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
9/28/2023	Federal-Tribes-States Legal/Technical Group Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin
10/3/2023	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
10/19/2023	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
10/25/2023	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
11/29/2023	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
11/30/2023	Inter-Tribal Council of Arizona	Tribal Leaders' Water Policy Council	Leaders from 21 tribes in Arizona
12/13/2023	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
12/14/2023	Gila River Indian Community	Government-to-government consultation	Tribal leadership, technical/legal staff
1/18/2024	Tribal Letter: Post-2026 Alternatives Development Consultation Request	Government-to-Government consultation request	Letter sent to tribal leaders of the 30 Basin Tribes
1/18/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
2/2/2024	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
2/14/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
2/15/2024	Federal-Tribes-States Legal/Technical Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin
2/22/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
2/28/2024	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
2/29/2024	Ak-Chin Indian Community	Government-to-government consultation	Tribal leadership, technical/legal staff
3/5/2024	Hualapai Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
3/21/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
4/3/2024	Quechan Indian Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
4/10/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
4/18/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
4/23/2024	Jicarilla Apache Nation	Government-to-government consultation	Tribal leadership, technical/legal staff
5/6/2024	Southern Ute Indian Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
5/10/2024	Inter-Tribal Council of Arizona	Tribal Leaders' Water Policy Council	Leaders from 21 tribes in Arizona
5/16/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
6/12/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
6/21/2024	Ute Mountain Ute Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
6/20/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
6/27/2024	Federal-Tribes-States Legal/Technical Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin
7/18/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
7/26/2024	Federal-Tribes-States Legal/Technical Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
8/8/2024	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
8/14/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
8/22/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
9/13/2024	Inter-Tribal Council of Arizona	Tribal Leaders Water Policy Council	Leaders from 21 tribes in Arizona
9/15/2024	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
9/17/2024	Federal-Tribes-States Legal/Technical Meeting	Provide updates on the Post-2026 process to the legal and technical representatives	Tribal legal and technical representatives for tribes throughout the Basin
9/19/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
10/7/2024	Ute Indian Tribe of Uintah and Ouray Reservation	Government-to-government consultation	Tribal leadership, technical/legal staff
10/9/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
10/17/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
11/6/2024	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
11/15/2024	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
11/20/2024	Federal-Tribes-States Leadership Meeting	Provide updates on the Post-2026 process to the tribal leadership	Tribal leaders for tribes throughout the Basin
11/21/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
12/5/2024	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
12/12/2024	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
12/19/2024	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
1/10/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
1/23/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
2/5/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
2/11/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
2/14/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
2/20/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
2/27/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
3/19/2025	Colorado River Indian Tribes	Government-to-government consultation	Tribal leadership, technical/legal staff
3/21/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
3/30/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
3/31/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
4/9/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
4/17/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
4/17/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
4/30/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
5/15/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
5/22/2025	Navajo Nation/ Hopi Tribe/ San Juan Southern Paiute Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
5/22/2025	30 Basin Tribes and Department Leadership	Meet Acting Assistant Secretary of Water and Science; Post-2026 updates	Tribal leaders, legal staff for 30 Basin tribes
5/23/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
5/28/2025	Ak-Chin Indian Community	Government-to-government consultation	Tribal leadership, technical/legal staff
5/28/2025	Fort Yuma Quechan Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
6/5/2025	Gila River Indian Community	Government-to-government consultation	Tribal leadership, technical/legal staff
6/5/2025	Colorado River Indian Community	Government-to-government consultation	Tribal leadership, technical/legal staff
6/5/2025	Navajo Nation and the Hopi Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
6/5/2025	Ute Mountain Ute Tribe, Southern Ute Indian Tribe, Jicarilla Apache Tribe, Ute Indian Tribe	Government-to-government consultation	Tribal leadership, technical/legal staff
6/11/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
6/26/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
7/23/2025	Tohono O'odham Nation	Provide updates on Post-2026 process to tribal leadership	Tribal leadership, technical/legal staff
7/24/2025	Tribal Flexible Elements Workgroup	Technical workgroup meeting	Tribal technical representatives
7/24/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
8/13/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
8/28/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
9/18/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
10/16/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
10/22/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
10/24/2025	Inter-Tribal Council of Arizona	Tribal Leaders' Water Policy Council	Leaders from 21 tribes in Arizona
11/14/2025	30 Basin Tribes and Department leadership	Meet Assistant Secretary of Water and Science; update on Post-2026 process; hear comments from tribes	Tribal leadership and technical/legal staff
11/20/2025	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
12/3/2025	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
12/5/2025	P26 Draft EIS Tribal Technical Session #1	A review of Draft EIS Alternatives and the analysis approach for tribal-related resources.	Tribal leaders and representatives for tribes throughout the Basin
12/19/2025	P26 Draft EIS Tribal Technical Session #2	A review of Lower Basin Shortage Distribution Methods, Models, and Comparison of Methods.	Tribal leaders and representatives for tribes throughout the Basin
1/15/2026	Tribal Letter: Draft EIS Consultation	Initiating tribal consultation on the Draft EIS	Letter sent to tribal leaders of the 30 Basin Tribes
1/15/26	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
2/2/20206	The Hopi Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/3/2026	P26 Draft EIS Tribal Technical Session #3	Approach to Post-2026 EIS resource analysis and how to interpret results.	Tribal leaders and representatives for tribes throughout the Basin
2/9/2026	Southern Ute Indian Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/9/2026	Ute Mountain Ute Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
2/10/2026	Jicarilla Apache Nation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/11/2026	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
2/11/2026	Yavapai Apache Nation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/12/2026	The Navajo Nation	P26 Technical Meeting	Tribal technical/legal staff
2/13/2026	Colorado River Indian Tribes	P26 Technical Meeting	Tribal technical/legal staff
2/13/2026	Ute Indian Tribe of Uintah and Ouray Reservation	P26 Technical Meeting	Tribal technical/legal staff
2/13/2026	Fort McDowell Yavapai Nation	P26 Technical Meeting	Tribal technical/legal staff
2/13/2026	Ak-Chin Indian Community	P26 Technical Meeting	Tribal technical/legal staff
2/17/2026	Hualapai Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/18/2026	Colorado River Indian Tribes	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/18/2026	Fort Yuma Quechan Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/19/2026	Gila River Indian Community	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/20/2026	Tohono O'odham Nation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/20/2026	The Navajo Nation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/23/2026	Kaibab Band of Paiute Indians	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/24/2026	Ak-Chin Indian Community	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
2/27/2026	Ute Indian Tribe of Uintah and Ouray Reservation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/2/2026	Moapa Band of Paiute Indians	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/2/2026	San Juan Southern Paiute	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/3/2026	Pascua Yaqui Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/4/2026	Fort McDowell Yavapai Nation	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
3/5/2026	Cocopah Indian Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/6/2026	San Carlos Apache Tribe	P26 Draft EIS Government-to-Government Consultation	Tribal leadership, technical/legal staff
3/19/2026	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
4/8/2026	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership
4/16/2026	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
5/6/2026	Upper Basin Tribes States Dialogue Meeting	Post-2026 Draft EIS Updates	Tribal Leaders and representatives from the six Upper Basin Tribes
5/8/2026	Final EIS Proposed Preferred Alternative	Technical call to present elements of the Final EIS Proposed Preferred Alternative framework	Tribal leaders and representatives for tribes throughout the Basin
5/19/2026	Fort Yuma Quechan Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
5/19/2026	Ute Mountain Ute Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
5/21/2026	Ute Indian Tribe of Uintah and Ouray Reservation Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
5/21/2026	Jicarilla Apache Nation Consultation	Final EIS Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
5/21/2026	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
5/26/2026	Southern Ute Indian Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
5/27/2026	Tohono O'odham Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
5/28/2026	Hualapai Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/1/2026	Colorado River Indian Tribes Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/2/2026	Ak-Chin Indian Community Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/2/2026	Gila River Indian Community Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/8/2026	Navajo Nation, Hopi Tribe, and San Juan Southern Paiute Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/8/2026	Basin Tribal Information Exchange	Water Year 27/28 Operations and the proposed Lower Basin Federal Water Resource Pool	Tribal leaders and representatives for tribes throughout the Basin
6/9/2026	Pascua Yaqui Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/9/2026	Basin Tribal Information Exchange – Arizona Priority 4 Water Tribes	Water Year 27/28 Operations and the proposed Lower Basin Federal Water Resource Pool	Tribal leadership and technical/legal staff from Arizona Priority 4 Water Tribes
6/10/2026	Yavapai Apache Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/10/2026	Ten Tribes Partnership Meeting	Bimonthly meeting with member tribes of the Ten Tribes Partnership	The 10 member tribes of the Ten Tribes Partnership

Date	Meeting Title/Subject of Correspondence	Purpose	Tribes Invited
6/10/2026	Fort McDowell Yavapai Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
6/25/2026	Basin Tribal Information Exchange	Monthly Meeting	Tribal leaders and representatives for tribes throughout the Basin
6/29/2026	Fort Mojave Indian Tribe Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff
7/1/2026	Navajo Nation Consultation	Final EIS Preliminary Preferred Alternative Government-to-Government Consultation	Tribal leadership, technical/legal staff

Appendix Q

Federal Register Notices

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APPENDIX Q. FEDERAL REGISTER NOTICES Q-1

Q.1 Request for Input on Development of Post-2026 Colorado River Reservoir Operational Strategies for Lake Powell and Lake Mead Under Historically Low Reservoir Conditions (Federal Register, June 24, 2022; 87 FR 37885) Q-2

Q.2 Notice of Intent To Prepare an Environmental Impact Statement and Notice To Solicit Comments and Hold Public Scoping Meetings on the Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead (Federal Register, June 16, 2023; 88 FR 39455) Q-7

Q.3 Colorado River Reservoir Operations: Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead (October 20, 2023 – 88 FR 72535) Q-11

Q.4 Environmental Impact Statements; Notice of Availability (U.S. Environmental Protection Agency, Federal Register, January 16, 2026; 91 FR 2131; FR Doc. No. 2026-00844) Q-13

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Appendix Q. Federal Register Notices

Four Federal Register notices have been issued to inform the public about the formulation of the interim operational guidelines and the preparation and availability of the Environmental Impact Statement. The full text of the Federal Register notices is provided in this appendix.

Q.1 Request for Input on Development of Post-2026 Colorado River Reservoir Operational Strategies for Lake Powell and Lake Mead Under Historically Low Reservoir Conditions (Federal Register, June 24, 2022; 87 FR 37885)

the individual turbines to the offshore substations, substation interconnector cables linking the substations to each other, offshore export cables, an onshore export cable system, 2 onshore substations, and connections to the existing electrical grid in New Jersey. The WTGs and offshore substations, inter-array cables, and substation interconnector cables would be located on the OCS approximately 13 nautical miles (15 statute miles) southeast of Atlantic City, New Jersey, within the area defined by Renewable Energy Lease OCS–A 0498 (Lease Area). The offshore export cables would be buried below the seabed surface in the OCS and State of New Jersey owned submerged lands. The onshore export cables, substations, and grid connections would be located in Ocean County and Cape May County, New Jersey.

Alternatives: BOEM considered 26 alternatives when preparing the DEIS and carried forward 6 alternatives for further analysis in the DEIS. These six alternatives include five action alternatives and the no action alternative. Twenty alternatives were rejected because they did not meet the purpose and need for the proposed action or did not meet screening criteria, which are presented in DEIS appendix C. The screening criteria included consistency with law and regulations; technical and economic feasibility; environmental impact; and geographic considerations.

Availability of the DEIS: The DEIS, Ocean Wind 1 COP, and associated information are available on BOEM's website at: *https://www.boem.gov/renewable-energy/state-activities/ocean-wind-1*. BOEM has distributed digital copies of the DEIS to all parties listed in DEIS appendix K, which also includes the location of all libraries receiving a copy. If you require a flash drive or paper copy, BOEM will provide one upon request, as long as copies are available. You may request a flash drive or paper copy of the DEIS by calling (703) 787–1520.

Cooperating Agencies: The following nine Federal agencies and State governmental entities participated as cooperating agencies in the preparation of the DEIS: Bureau of Safety and Environmental Enforcement; U.S. Environmental Protection Agency; National Marine Fisheries Service; U.S. Army Corps of Engineers; U.S. Coast Guard; U.S. Fish and Wildlife Service, Department of Defense; New Jersey Department of Environmental Protection; and New York State Department of State. The National Park Service participated as a participating agency.

Information on Submitting Comments: BOEM does not consider anonymous comments. Please include your name and address as part of your comment. BOEM makes all comments, including the names and addresses of respondents, available for public review online and during regular business hours. Individual respondents may request that BOEM withhold their names, addresses, or any other personal identifiable information (PII) included in their comment from the public record; however, BOEM cannot guarantee that it will be able to do so. If you wish your name, address, or other PII to be withheld, you must state your request prominently in a cover letter and explain the harm that you fear from its disclosure such as unwarranted privacy invasion, embarrassment, or injury. All submissions from organizations or businesses and from individuals identifying themselves as representatives or officials of organizations or businesses will be made available for public inspection in their entirety.

Authority: 42 U.S.C. 4231 *et seq.* (NEPA, as amended) and 40 CFR 1506.6.

William Y. Brown,

Chief Environmental Officer, Bureau of Ocean Energy Management.

[FR Doc. 2022–13490 Filed 6–23–22; 8:45 am]

BILLING CODE 4310–MR–P

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

[RR03040000.22XR068080.RX.18786000.5004001]

Request for Input on Development of Post-2026 Colorado River Reservoir Operational Strategies for Lake Powell and Lake Mead Under Historically Low Reservoir Conditions

AGENCY: Bureau of Reclamation, Interior.

ACTION: Notice and request for input.

SUMMARY: The Secretary of the Interior has directed the Bureau of Reclamation (Reclamation) to begin work to develop operating strategies for the continued coordinated operation of Lake Powell and Lake Mead. A number of reservoir and water management decisional documents and agreements that govern operation of Colorado River facilities and management of Colorado River water are currently scheduled to expire at the end of 2026. These include the December 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), among other important management documents, both within the United States, as well as international agreements between the United States and Mexico pursuant to the United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty).

DATES: Submit written comments on the proposed development of Post-2026 Colorado River Operational Strategies pursuant to this notice on or before September 1, 2022.

Reclamation will host two public webinars to summarize the content and purpose of this **Federal Register** notice. The webinars will take place on Tuesday, July 12, 2022, from 10 a.m. to 11 a.m. (MDT), and on Thursday, July 14, 2022, from 10 a.m. to 11 a.m. (MDT).

ADDRESSES: Send written comments on the proposed development of Post-2026 Colorado River Operational Strategies to *CRB-info@usbr.gov*.

The virtual meeting held on Tuesday, July 12, 2022, may be accessed at *https://teams.microsoft.com/l/meetup-join/19%3ameeting_YTg1ZmVmMDItNzkxMC00YjM2LTg3NmEtNmIwMWI3ZGEyNjJm%40thread.v2/0?context=%7b%22Tid%22%3a%220693b5ba-4b18-4d7b-9341-f32f400a5494%22%2c%22Oid%22%3a%22388b569b-9117-49f0-b6f1-cd12ff0587b0%22%7d;* or call in (audio only) at (719) 733–3211, Phone Conference ID: 100 899 510#.

The virtual meeting held on Thursday, July 14, 2022, may be accessed at *https://teams.microsoft.com/l/meetup-join/19%3ameeting_MWE0YmZhNDItOGQwZC00YmRiLWJiMmItZDM4ZDUwN2JlNzcx%40thread.v2/0?context=%7b%22Tid%22%3a%220693b5ba-4b18-4d7b-9341-f32f400a5494%22%2c%22Oid%22%3a%22e792bef3-e313-4746-82d1-a6064d5ee897%22%7d;* or call in (audio only) at (202) 640–1187, Phone Conference ID: 795 497 392#.

FOR FURTHER INFORMATION CONTACT: Carly Jerla, Senior Water Resources Program Manager, Bureau of Reclamation, at (303) 517–1160; or by email at *cjerla@usbr.gov*. Individuals in the United States who are deaf, deafblind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services. Individuals outside the United States should use the relay services offered within their country to make international calls to the point-of-contact in the United States.

SUPPLEMENTARY INFORMATION: Through this notice, and prior to formally initiating a National Environmental Policy Act (NEPA) process (or processes) to develop post-2026 operations for Lake Powell and Lake Mead (among other potential actions), Reclamation is requesting input on: (a) processes that can be employed to encourage and facilitate meaningful participation of Colorado River Basin (Basin) partners, stakeholders, and the general public in the anticipated upcoming NEPA process(es); as well as (b) potential substantive elements and strategies for post-2026 operations to consider in the anticipated upcoming NEPA process(es). Reclamation anticipates formally initiating the NEPA process through a Notice of Intent to Prepare an Environmental Impact Statement in the **Federal Register** in early 2023. As noted in more detail below, given current conditions in the Colorado River Basin, Reclamation may utilize multiple NEPA efforts, or other appropriate processes, to address emerging low-reservoir conditions in the Basin.

The Colorado River Basin provides essential water supplies to approximately 40 million people, nearly 5.5 million acres of agricultural lands, and habitat for ecological resources across the Southwestern United States and Northwestern Mexico. The limited water supplies of the Colorado River are declining and the Colorado River Basin is currently experiencing a prolonged period of drought and record-low runoff conditions resulting in historically low reservoir levels at Lake Powell and Lake Mead. The period from 2000 through 2022 is the driest 23-year period in more than a century and one of the driest periods in the last 1,200 years. Absent a change in hydrologic conditions, water use patterns, or both, Colorado River reservoirs will continue to decline to critically low elevations threatening essential water supplies across nine states in the United States and the Republic of Mexico (Mexico). It is foreseeable that without appropriate responsive actions and under a continuation of recent hydrologic trends, major Colorado River reservoirs could continue to decline to ''dead pool''—elevations at which water cannot be regularly released from a reservoir—in coming years. As stated in the 2019 Lower Basin Drought Contingency Plan:

> . . . as a result of actual operating experience subsequent to the adoption of the 2007 Interim Guidelines, as well as emerging scientific information regarding the increasing variability and anticipated decline in Colorado River flow volumes, the Parties recognize and acknowledge that entities that rely on the Colorado River as a water source face increased individual and collective risk of temporary or prolonged interruptions in water supplies, with associated adverse impacts on the society, environment and economy of the southwestern United States.

The current unprecedented drought and low-runoff conditions are anticipated to persist and potentially worsen as a result of a number of factors, including increasing temperatures in the Basin, and other effects of climate change.

As a result of the exceptionally low runoff conditions over the past 3 years (2020, 2021, and 2022), unprecedented drought response operations have been triggered at Lake Powell and Lake Mead consistent with the 2007 Interim Guidelines and agreements adopted pursuant to the 2019 Colorado River Drought Contingency Plan Authorization Act (Pub. L. 116–14) (the 2019 Drought Contingency Plan (DCP) Act). The unprecedented risks facing the Colorado River Basin was the subject of a June 14, 2022 U.S. Senate hearing in which Reclamation Commissioner Camille Touton noted that while no one knows how dry the next few years could be, if recent (2018-present) dry conditions continue, Lake Powell and Lake Mead face extraordinary risks over the next 12–24 months, and that additional actions are needed to protect the reservoirs from rapidly declining to critically-low elevations: reductions totaling millions of acre-feet in reductions of use across the Basin could be needed to stabilize the reservoirs.

Background on Development of the 2007 Interim Guidelines.

Initially spurred by a 5-year period in which Lake Powell and Lake Mead lost nearly half of the combined storage in the reservoirs as a result of an ongoing multi-year drought, decreasing overall system storage, and growing demands for Colorado River water, at the direction of the Secretary of the Interior, Reclamation initiated a NEPA process in 2005 to develop operating guidelines for the coordinated operations of Lake Powell and Lake Mead, along with Lower Basin shortage criteria (and other related actions). See 70 FR 57322 (September 30, 2005). Following completion of the NEPA process (and associated compliance activities), in December 2007 Secretary of the Interior Kempthorne approved the Record of Decision for the 2007 Interim Guidelines. Published at 73 FR 19873 (April 11, 2008). The 2007 Interim Guidelines provided objective operating criteria for the coordinated operations of Lake Powell and Lake Mead and for determining Lower Basin shortage conditions, as well as establishing a program to encourage water conservation actions in the Lower Basin.

Operational Agreements, Operating Experience and Changed Circumstances Since Adoption of the 2007 Interim Guidelines.

Operational Agreements

Since their adoption, the 2007 Interim Guidelines have provided operating criteria for Lake Powell and Lake Mead including provisions designed to provide a greater degree of certainty to water users about timing and volumes of potential water delivery reductions, as well as additional operating flexibility to conserve and enhance water storage in Colorado River system reservoirs. In 2012, the United States and Mexico adopted Minute 319, a binational agreement adopted pursuant to the 1944 Water Treaty. Minute 319 provided interim (2012–2017) operating provisions that implement the provisions of the 1944 Water Treaty, establishing objective criteria for treaty deliveries through a wide range of reservoir conditions, and established mechanisms that provide Mexico with the flexibility to reduce water use and defer delivery of the reduced volumes in subsequent years. Minute 319 also provided U.S. funding to enhance water conservation and riparian habitat in the Colorado River Delta and Limitrophe region.

Notwithstanding the elements of the 2007 Interim Guidelines (and Minute 319), as hydrologic conditions worsened thereby increasing the risk of reservoirs declining to critically-low conditions, in 2013–2014, Reclamation and stakeholders began pursuing additional adaptive management actions. Among other drought response activities, the Upper and Lower Basin DCPs were adopted pursuant to the 2019 DCP Act. A further agreement with Mexico in 2017 (Minute 323) had previously established enhanced water reduction, water conservation, and savings mechanisms pursuant to the 1944 Water Treaty. Both the 2007 Interim Guidelines and the DCPs are anticipated to be in place for an interim period through 2026.[1] Similarly, Minute 323 is anticipated to be in effect through 2026.

[1] Except for the special provisions described in Section XI.G.8. of the 2007 Interim Guidelines, the 2007 Interim Guidelines are anticipated to remain in effect through December 31, 2025 (through preparation of the 2026 Annual Operating Plan). With the exception of certain Intentionally Created Surplus recovery and Upper Basin demand management provisions, operations under the

Continued

2020 Review of Operating Experience

The interim nature of the 2007 Interim Guidelines has provided the opportunity to gain valuable experience in the management of Lake Powell and Lake Mead under the adopted operations, improving the basis for making future operational decisions, both during the interim period and after. Section XI.G.7.D. of the 2007 Interim Guidelines required the documentation of this experience and an evaluation of the effectiveness of the 2007 Interim Guidelines. In fulfillment of this provision, in December 2020, Reclamation published on its website its ''Review of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead'' (the 2020 7.D. Review).

The purpose of the 2007 Interim Guidelines was determined in the early stages of the NEPA process led by Reclamation to develop the guidelines and consists of 3 components. As stated in Section IV of the 2007 Interim Guidelines, the purpose is to:

- ''improve Reclamation's management of the Colorado River by considering trade-offs between the frequency and magnitude of reductions of water deliveries, and considering the effects on water storage in Lake Powell and Lake Mead, and on water supply, power production, recreation, and other environmental resources;
- provide mainstream United States users of Colorado River water, particularly those in the Lower Division states, a greater degree of predictability with respect to the amount of annual water deliveries in future years, particularly under drought and low reservoir conditions; and
- provide additional mechanisms for the storage and delivery of water supplies in Lake Mead to increase the flexibility of meeting water use needs from Lake Mead, particularly under drought and low reservoir conditions.''

The 2020 7.D. Review found that the 2007 Interim Guidelines were largely effective as measured against this stated purpose.

However, with respect to the 4 operational elements of the 2007 Interim Guidelines (Coordinated Operations of Lake Powell and Lake Mead, Lower Basin Surplus Guidelines, Lower Basin Shortage Guidelines, and Storage and Delivery of Conserved Water in the Lower Basin), the 2007 Interim Guidelines failed to provide sufficiently robust operating provisions to address the increasing severity of the drought and low runoff conditions exacerbated by climate change. By 2013–2014, as a result of the worsening drought, a broad consensus within the Basin emerged that additional actions were needed to reduce the risk of Lake Powell and Lake Mead reaching critically low elevations. This led to the adoption of the DCPs and other voluntary adaptive actions.

The 2020 7.D. Review also documented important considerations for enhancing future effectiveness: (1) enhanced flexibilities and transparency for water users; (2) expanded participation in conservation and Basin-wide programs; (3) increased consideration of the linkage that occurs through coordinated reservoir operations, particularly with respect to the uncertainties inherent in model projections used to set operating conditions; and (4) more robust measures to protect reservoir levels.

Reclamation received written input during the 2020 7.D. Review process from a diverse group of partners and stakeholders across the Colorado River Basin. One area of significant comment was with respect to the stakeholder engagement process used to develop the 2007 Interim Guidelines. Multiple commenters expressed that the process was inadequate to meaningfully engage a sufficiently diverse group of stakeholders. Given the increased partner and stakeholder participation in Basin decision-making processes since the adoption of the 2007 Interim Guidelines, the Department of the Interior (Department or Interior) is particularly focused on developing and implementing a process that facilitates and encourages meaningful participation of Basin partners and stakeholders including other Federal agencies, the seven Colorado River Basin States, Native American Tribes, non-governmental organizations (NGOs), academic experts, and the general public. As discussed below, the Department is also committed to identifying processes that can complement the efforts of the International Boundary and Water Commission (IBWC) to develop post-2026 agreements that would succeed current agreements contained in Minute 323.

Changed Circumstances Since Adoption of the 2007 Interim Guidelines

As Reclamation and the Department prepare to initiate a NEPA process for the post-2026 Colorado River Reservoir Operational Strategies for Lake Powell and Lake Mead under historically low reservoir conditions, it is important to succinctly highlight a few areas where circumstances have changed since adoption of the 2007 Interim Guidelines. Reclamation welcomes input on these changed circumstances as well as suggestions on potential strategies that would be appropriate to more successfully address these changed circumstances given the expectation that conditions will continue to change in the Colorado River Basin in the years and decades ahead.

1. With respect to issues involving hydrology, risk facing the Basin, and advances in scientific understandings:

Since 2000, 50 percent of these years have seen less than 11 million acre-feet (maf) of annual natural flow at Lees Ferry and 13 percent have seen less than 8 maf. The 21st century has been 20 percent drier than the 20th century, and the 5-year average has declined by 33 percent in 23 years. Future strategies should consider these conditions and the likelihood of continued declines in supply.

The 2007 Interim Guidelines were developed in response to 5 years of drought and precipitous reservoir declines and were based primarily on the modeling assumption of a stationary climate where future inflows were adequately represented in the observed historical record.

Since 2007, unprecedented drought has changed our understanding of basin hydrology; climate science tells us that the future temperatures in the Colorado River Basin will continue to warm and that we can expect an increased likelihood of experiencing deep, prolonged droughts.

The 2020 7.D. Review found that while the 2007 Interim Guidelines were effective at meeting their overall purpose, the increasing severity of the drought demonstrated that the 2007 Interim Guidelines were insufficiently robust to protect reservoir storage, requiring the adoption of the DCPs and other responsive adaptive actions.

Nevertheless, even the additional actions adopted subsequent to the 2007 Interim Guidelines were demonstrably insufficient to address the ongoing drought and low runoff conditions. With declining reservoir conditions, Reclamation undertook emergency and other drought response actions in both 2021 and 2022 to protect infrastructure and operations at Glen Canyon Dam.

The latest global climate model-derived projections of climate change agree that temperatures will warm, but precipitation and impacts on basin hydrology continue to show a wide range of potential futures and experts cannot say with a high degree of confidence or specificity what is most likely to happen in a nonstationary

Guidelines and the DCPs are in effect through December 31, 2026.

climate (*i.e.,* the question ''what will future runoff be?'' cannot be answered). Hydrologic uncertainty combined with uncertain future growth and water use compound to mean that it is impossible to assign probabilities to any given future and the basin is experiencing conditions of deep uncertainty.

These factors lead Reclamation to observe that in developing post-2026 guidelines in a nonstationary, drying system, a different approach toward addressing risk that employs planning methods that account for deep uncertainty must be taken. Such an approach should enhance the ability to identify robust policies that are better prepared to adapt to changing conditions.

For planning purposes, robust policies are those that withstand a broad range of future conditions and are not based on a single set of assumptions about water supply and demand. With increasing temperatures across the basin, predictions of commensurate decreases in reliable supply, and uncertainty in future demands, Reclamation believes that future policies must be tested across a wide range of potential future conditions, including drought sequences that are longer and more severe than those that have been observed. Absent such an approach, policies are likely to be insufficiently robust, adaptable, and successful.

2. With respect to issues regarding engagement and inclusivity in Colorado River decision-making:

The domestic stakeholder process used to develop the 2007 Interim Guidelines was considered, at the time, to have engaged a wide range of stakeholders and included extensive public involvement. Central to this process was technical outreach and modeling support provided by Reclamation.

In the intervening 15 years, there has been an increasing level of collaboration and communication across the Basin—indicating the necessity of more deeply engaging a broader range of stakeholders during the upcoming process(es). Meaningfully engaging and encouraging the participation of Colorado River Basin Tribes, representatives of Mexico, and NGOs was crucial to the success of the key and essential operational decisions that have come about since the adoption of the 2007 Interim Guidelines.

As we approach the initiation of efforts to develop post-2026 guidelines, Reclamation has identified that it intends to design and implement a stakeholder process that is inclusive, transparent, and encourages meaningful engagement. In order to accomplish this commitment, Reclamation intends to prioritize stakeholder technical education, technical outreach, and timely access to relevant technical information. Reclamation intends to support parties in developing strategies and would welcome input on recommended steps to ensure active participation by a wide range of Basin partners, stakeholders, and the general public. Reclamation will continue to seek to prioritize the development of approaches that have broad-based support.

a. With respect to Colorado River Basin Tribes:

During the preparation of the 2007 Interim Guidelines, the Department conducted extensive engagement with Native American Tribes in the Colorado River Basin (Basin Tribes) regarding the potential adoption of operating guidelines for Lake Powell and Lake Mead and related actions, including the adoption of rules regarding creation, accounting and delivery of Intentionally Created Surplus. See 2007 Final Environmental Impact Statement (FEIS), Appendix I, at *https://www.usbr.gov/lc/region/programs/strategies/FEIS/AppI.pdf.*

Notwithstanding the engagement documented in the 2007 FEIS, during the implementation of the 2007 Interim Guidelines, many Basin Tribes have expressed deeply-held concerns, viewpoints, and objections to the lack of full engagement and consultation, and that any engagement during the development (and implementation) of the 2007 Interim Guidelines was insufficient to address the range of interests, needs, and fundamental rights of the Basin Tribes. These concerns have significantly increased as water supply conditions in the Basin have been increasingly impacted by drought, low runoff, and the effects of climate change.

Interior has undertaken extensive efforts across the Basin to facilitate Indian Water Rights Settlements, enhance Tribal utilization of water rights, engage with Tribal Governments, and facilitate Basin engagement. For example, beginning last year, Reclamation has hosted monthly Tribal Information Exchanges as one mechanism to share timely information on Colorado River Basin conditions, challenges, and opportunities for investment and water conservation programs. While these efforts have continuously increased over time, there are extraordinary and unique challenges facing Basin Tribes.

Basin Tribes have expressed their concerns in direct correspondence to the Secretary of the Interior and have formally requested commitments from Interior for greater inclusion in the NEPA process to develop post-2026 operations, as well as increased engagement and consultation during the implementation of any guidelines developed pursuant to the upcoming NEPA process.

Interior recognizes that each Basin Tribe possesses unique rights (including water rights), unique viewpoints, and concerns with respect to current and projected conditions in the Basin. While it is premature at this time for Interior to make precise decisions about the content of post-2026 operations, the Secretary of the Interior has and is committed to engage and consult with the Basin Tribes in a meaningful and transparent manner during the upcoming NEPA process and to fully consider tribal input and viewpoints through government-to-government consultation, consistent with the Department's Detailed Plan for Improving Interior's Implementation of Executive Order 13175, *Consultation and Coordination with Indian Tribes,* found at *www.doi.gov/priorities/tribal-consultation.* Interior is interested in receiving specific input on the most effective processes that can be employed during the upcoming NEPA process(es) to ensure that these commitments are fully implemented.

b. With respect to engagement with Mexico:

The 2007 Interim Guidelines were adopted under the authority of the Secretary of the Interior. Accordingly, the scope of the 2007 Interim Guidelines was domestic, and no decisions were made regarding operations under the 1944 Water Treaty.

Since 2007 an extraordinary cooperative process has been forged between the two nations with the participation of the Department and Reclamation in support of agreements developed between the United States and Mexico Sections of the IBWC. Since adoption of the 2007 Interim Guidelines, significant international agreements on the Colorado River are memorialized in Minutes 316, 317, 318, 319, and 323.

With Minute 323 scheduled to expire at the same time as the 2007 Interim Guidelines and the 2019 DCP, the United States and Mexico have expressed a policy goal of developing a successor to Minute 323 on a parallel timeline as the domestic development of post-2026 operational approaches. This policy goal is intended to ensure that Colorado River reservoirs continue to be managed in a manner that ensures an

appropriate degree of operational alignment.

While not determining in any way what processes the IBWC may choose to utilize, the Department would welcome input on how the Interior-led domestic planning processes could be implemented in a coordinated and complementary fashion to those of the IBWC.

3. With respect to the current and emerging operational challenges and potential for significant disruptions to Colorado River water supplies under continued low-runoff conditions:

While previous actions, especially the DCP, were intended to preserve Reclamation's ability to undertake post-2026 planning with a stable system and avoid crisis planning, very dry hydrology since the adoption of the DCP has resulted in Lake Powell and Lake Mead nearing critically low elevations.

Should the conditions continue or worsen, we recognize that in addition to post-2026 planning under the anticipated NEPA process(es), Reclamation may likely need to also prioritize implementation of near-term actions to stabilize the decline in reservoir storage and prevent system collapse. Reclamation has not yet determined what additional actions or processes may be required to address these near-term operational risks. It is anticipated that near-term response actions and development of post-2026 operations will need to proceed on parallel timelines.

- *Process:* Reclamation seeks specific input on suggested mechanisms for the anticipated NEPA process(es) to ensure that a wide range of Basin partners, stakeholders, and the general public can meaningfully engage and participate in the development of post-2026 operational strategies.
- *Substantive elements of post-2026 operations:* Reclamation seeks input on potential substantive elements and strategies that should be considered for post-2026 operations and considered in the anticipated upcoming NEPA process(es).

With respect to both these areas where Reclamation is seeking input through this **Federal Register** notice, Reclamation is particularly interested in receiving specific recommendations that can be considered and potentially integrated as the initiation of the NEPA process is being developed.

Reclamation notes that it intends to formally initiate the NEPA process for development of post-2026 operations through a Notice of Intent to Prepare an Environmental Impact Statement in the **Federal Register** in early 2023. Any input received as part of this **Federal Register** notice request for input will be fully considered by Reclamation but formal scoping comments will be solicited following initiation of the anticipated NEPA process. Decisions by entities whether or not to submit input regarding this **Federal Register** notice shall not limit or prejudice in any manner comments such entities may choose to submit during the formal scoping period following a formal Notice of Intent to initiate preparation of an Environmental Impact Statement (anticipated in early 2023).

Public Disclosure of Comments

Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Tanya Trujillo,

Assistant Secretary for Water and Science.

[FR Doc. 2022–13502 Filed 6–23–22; 8:45 am]

BILLING CODE 4332–90–P

INTERNATIONAL TRADE COMMISSION

Notice of Receipt of Complaint; Solicitation of Comments Relating to the Public Interest

AGENCY: U.S. International Trade Commission.

ACTION: Notice.

SUMMARY: Notice is hereby given that the U.S. International Trade Commission has received a complaint entitled *Certain Mobile Electronic Devices, DN 3625;* the Commission is soliciting comments on any public interest issues raised by the complaint or complainant's filing pursuant to the Commission's Rules of Practice and Procedure.

FOR FURTHER INFORMATION CONTACT: Lisa R. Barton, Secretary to the Commission, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, telephone (202) 205–2000. The public version of the complaint can be accessed on the Commission's Electronic Document Information System (EDIS) at *https://edis.usitc.gov.* For help accessing EDIS, please email *EDIS3Help@usitc.gov.*

General information concerning the Commission may also be obtained by accessing its internet server at United States International Trade Commission (USITC) at *https://www.usitc.gov.* The public record for this investigation may be viewed on the Commission's Electronic Document Information System (EDIS) at *https://edis.usitc.gov.* Hearing-impaired persons are advised that information on this matter can be obtained by contacting the Commission's TDD terminal on (202) 205–1810.

SUPPLEMENTARY INFORMATION: The Commission has received a complaint and a submission pursuant to § 210.8(b) of the Commission's Rules of Practice and Procedure filed on behalf of Maxell, Ltd. on June 16, 2022. The complaint alleges violations of section 337 of the Tariff Act of 1930 (19 U.S.C. 1337) in the importation into the United States, the sale for importation, and the sale within the United States after importation of certain mobile electronic devices. The complainant names as respondents: Lenovo Group Ltd. of China; Lenovo (United States) Inc. of Morrisville, NC; and Motorola Mobility LLC of Libertyville, IL. The complainant requests that the Commission issue a limited exclusion order, cease and desist orders, and impose a bond upon respondents alleged infringing articles during the 60-day Presidential review period pursuant to 19 U.S.C. 1337(j).

Proposed respondent, other interested parties, and members of the public are invited to file comments on any public interest issues raised by the complaint or § 210.8(b) filing. Comments should address whether issuance of the relief specifically requested by the complainant in this investigation would affect the public health and welfare in the United States, competitive conditions in the United States economy, the production of like or directly competitive articles in the United States, or United States consumers.

In particular, the Commission is interested in comments that:

(i) explain how the articles potentially subject to the requested remedial orders are used in the United States;

(ii) identify any public health, safety, or welfare concerns in the United States relating to the requested remedial orders;

(iii) identify like or directly competitive articles that complainant, its licensees, or third parties make in the United States which could replace the subject articles if they were to be excluded;

(iv) indicate whether complainant, complainant's licensees, and/or third party suppliers have the capacity to

Q.2 Notice of Intent To Prepare an Environmental Impact Statement and Notice To Solicit Comments and Hold Public Scoping Meetings on the Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead (Federal Register, June 16, 2023; 88 FR 39455)

Federal Register / Vol. 88, No. 116 / Friday, June 16, 2023 / Notices 39455

and not competing requests. California State University, Sacramento is responsible for sending a copy of this notice to the Indian Tribes identified in this notice.

Authority: Native American Graves Protection and Repatriation Act, 25 U.S.C. 3003, and the implementing regulations, 43 CFR 10.9, 10.10, and 10.14.

Dated: June 6, 2023.

Melanie O'Brien,

Manager, National NAGPRA Program.

[FR Doc. 2023–12857 Filed 6–15–23; 8:45 am]

BILLING CODE 4312–52–P

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

[RR03040000, 23XR0680A1, RX187860005004001]

Notice of Intent To Prepare an Environmental Impact Statement and Notice To Solicit Comments and Hold Public Scoping Meetings on the Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

AGENCY: Bureau of Reclamation, Interior.

ACTION: Notice and request for comments.

SUMMARY: The Secretary of the Interior (Secretary) has directed the Bureau of Reclamation (Reclamation) to develop post-2026 Colorado River reservoir operational guidelines and strategies for Lake Powell and Lake Mead (referred to as "post-2026 operations"). Several important reservoir and water management decisional documents and agreements that govern operation of Colorado River facilities and management of Colorado River water are currently scheduled to expire at the end of 2026. Through this **Federal Register** notice, Reclamation is formally initiating the process to prepare an environmental impact statement (EIS) for the development of post-2026 operations.

DATES: This **Federal Register** notice initiates the public scoping process for the EIS. Reclamation requests that the public submit comments concerning the scope of specific operational guidelines, strategies, and any other issues that should be considered on or before August 15, 2023.

Reclamation will host three virtual public meetings/webinars to provide summary information and receive oral comments:

- Monday, July 17, 2023, 1 p.m. to 2 p.m. (MDT)
- Tuesday, July 18, 2023, 10 a.m. to 11 a.m. (MDT)
- Monday, July 24, 2023, 6 p.m. to 7 p.m. (MDT)

ADDRESSES: Please send written comments pursuant to this notice to *crbpost2026@usbr.gov* or Bureau of Reclamation, Attn: Post-2026 (Mail Stop 84–55000), P.O. Box 25007, Denver, CO 80225.

The registration link for the webinar held on Monday, July 17, 2023, is *https://swca.zoom.us/webinar/register/WN_-_hvFoMcRJ-l98k4n7-GvQ,* or the dial in option (audio only) is (602) 753–0140 or (720) 928–9299; Webinar ID: 918 5524 0606.

The registration link for the webinar held on Tuesday, July 18, 2023, is *https://swca.zoom.us/webinar/register/WN_sbSwzBJhQ66Z-E65TGXX1g,* or the dial in option (audio only) is (602) 753–0140 or (720) 928–9299; Webinar ID: 963 7946 3234.

The registration link for the webinar held on Monday, July 24, 2023, is *https://swca.zoom.us/webinar/register/WN_r0ozNRpmRu-hmEpYxe0-Qg,* or the dial in option (audio only) is (602) 753–0140 or (720) 928–9299; Webinar ID: 949 1587 3150.

FOR FURTHER INFORMATION CONTACT: Amanda Erath, Colorado River Post-2026 Program Coordinator, Bureau of Reclamation, at (303) 445–2766, or by email at *crbpost2026@usbr.gov*. Please also visit the project website at *https://www.usbr.gov/ColoradoRiverBasin/Post2026Ops.html*. Individuals in the United States who are deaf, deafblind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services. Individuals outside the United States should use the relay services offered within their country to make international calls to the point-of-contact in the United States.

SUPPLEMENTARY INFORMATION: This document provides notice that Reclamation intends to prepare an EIS for post-2026 operations and conduct public scoping. Reclamation is issuing this **Federal Register** notice pursuant to the National Environmental Policy Act of 1969, as amended (NEPA), 42 U.S.C. 4321 *et seq.;* the Council on Environmental Quality's regulations for implementing NEPA, 43 CFR parts 1500 through 1508; and the Department of the Interior (Department or Interior) NEPA regulations, 43 CFR part 46.

Background

The Colorado River Basin has been in a prolonged period of drought and low-runoff conditions, and despite current projections of 2023 runoff being well above average, the period from 2000 through 2023 is currently estimated as the second driest period in more than a century and one of the driest periods in the last 1,200 years. From 2000 to 2004, Lake Powell and Lake Mead lost nearly half of their combined storage. The onset of this period of acute drought spurred the development of the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines). Over the past 15 years since the adoption of the 2007 Interim Guidelines, as drought and low-runoff conditions continued, additional responsive actions were needed to complement the 2007 Interim Guidelines (*e.g.,* 2019 Colorado River Basin Drought Contingency Plan (DCP)). At the end of 2026, a number of reservoir and water management decisional documents and agreements that govern the operation of Colorado River facilities and management of the Colorado River are scheduled to expire. These include the 2007 Interim Guidelines, the DCP, and other important management documents within the United States, as well as Minute 323 between the United States and Mexico pursuant to the United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty).

Since 2021, the Department has undertaken several actions to protect critical infrastructure in response to declining reservoir elevations and the deepening of drought conditions from 2020 to 2022. As the summer of 2022 ended with near record low elevations in Lake Powell and Lake Mead, the Department recognized that, absent a change in hydrologic conditions, water use patterns, or both, Colorado River reservoirs would continue to decline to critically low elevations before the 2007 Interim Guidelines expired. In order to modify guidelines for the operation of Glen Canyon and Hoover Dam for the remainder of the interim period (through 2026) to address these historic drought and low runoff conditions in the Basin, the Department initiated a NEPA process on November 17, 2022, to prepare a Supplemental Environmental Impact Statement (SEIS) for Near-term Colorado River Operations. The draft SEIS was released for public review on April 14, 2023. In light of the Lower Basin states' consensus-based system conservation proposal submitted on May 22, 2023, the Department temporarily withdrew the draft SEIS so

that it can fully analyze the effects of the proposal under NEPA. Reclamation intends to publish an updated draft SEIS for public comment with the consensus-based proposal as an action alternative and finalize the SEIS process later this year.

Recognizing the need to begin to develop long-term strategies for Colorado River operations while simultaneously addressing the current drought conditions and preparing for the potential of continuing low runoff and low reservoir conditions, the Department published a **Federal Register** notice on June 24, 2022 (87 FR 37884), related to post-2026 operations. In that **Federal Register** notice, the Department specifically requested public input on procedural approaches to developing the post-2026 operational strategies (process) and potential substantive elements of post-2026 operations. In response, the Department received substantial input from States, Tribes, water districts, non-governmental organizations, and the public. The input received has been summarized in a ''Pre-Scoping Summary Report'' (Available at *https://www.usbr.gov/ColoradoRiverBasin/documents/Post-2026_Pre-Scoping%20Comment%20Summary%20Final_Updated1.30.2023_508.pdf*) and is being considered and integrated into this NEPA process. This NOI follows that important early opportunity for public input, and formally initiates the post-2026 NEPA process.

With respect to the relationship between the ongoing SEIS process and the post-2026 process, the November 2022 **Federal Register** notice was clear that the SEIS: ''does not interfere with, supplant, or supersede that separate post-2026 guidelines development process. Rather, this SEIS will inform and complement the development of post-2026 guidelines.'' The SEIS is focused on limited sections of the 2007 Interim Guidelines to develop the operational tools necessary to address potential extreme drought conditions during the 2024 to 2026 timeframe. In contrast, the post-2026 process will address the subsequent timeframe and revisit all sections of the 2007 Interim Guidelines and other operating agreements that expire in 2026 (*e.g.*, the DCP). The appropriate scope of post-2026 operations will be determined after conclusion of the public scoping process.

The June 2022 **Federal Register** notice for pre-scoping for post-2026 operations anticipated ''that near-term response actions and development of post-2026 operations will need to proceed on parallel timelines.'' The SEIS and post-2026 processes are now underway and proceeding simultaneously as predicted. Every effort will be made to provide clear and timely information regarding the milestones for public engagement in the post-2026 process to minimize the stakeholder and public burden of tracking and engaging in both efforts.

Purpose of This Notice of Intent

To assure the continued stability of the Colorado River system into the future, Reclamation announces its intent to prepare an EIS for post-2026 operations and is now soliciting public comments on the scope of specific operational guidelines, strategies, and any other related issues that should be considered in the upcoming EIS.

Reclamation invites all interested members of the public, including the seven Colorado River Basin States, Tribes, water and power contractors, representatives of the agricultural industry, municipal water providers, environmental organizations, representatives of the recreation industry, representatives of academic and scientific communities and other organizations and agencies to provide oral and written comments. Reclamation anticipates publishing a ''scoping report'' after completion of the public scoping meetings and the close of the comment period identified in this **Federal Register** notice.

All comments received will be considered as Reclamation develops the proposed federal action, Purpose and Need, and scope of the analysis (*e.g.*, affected area, geographic scope, time horizon/term). Similar to operational guidelines currently in place, it is likely that the post-2026 operational guidelines will be interim. Despite their interim nature, it is the Department's intent that these operational guidelines and strategies are sufficiently robust and adaptive and can withstand a broad range of future conditions thereby providing greater operational and planning stability to water users and the public throughout the Colorado River Basin.

June 2022 Request for Input on Development of Post-2026 Colorado River Operational Strategies

In response to the June 2022 pre-scoping **Federal Register** notice, Reclamation heard from over 80 stakeholders and partners as well as over 2,000 members of the public. As noted above, in January 2023, Reclamation published a ''Pre-Scoping Comment Summary Report'' on its website describing and summarizing the input received and hosted a public outreach event on January 30, 2023, to communicate the findings.

The input received in response to the June 2022 **Federal Register** notice included a broad range of comments and suggestions, not all of which can be addressed in this proposed process or described in this NOI. In addition, some suggestions may be part of ongoing or future efforts. However, some widely expressed themes related to the nature of future operational guidelines and strategies are actively being considered in our approach during the early stages of planning for this NEPA process:

- Future operational guidelines and strategies must support proactive management to improve system stability and avoid continuously managing in response to crises. To achieve this, future operational guidelines and strategies must be capable of both withstanding a broad range of future hydrologic and operating conditions and minimizing system vulnerability, *i.e.*, they must be more robust and adaptive than current strategies.
- Future operational guidelines and strategies should incorporate a more holistic approach to Colorado River water management in a way that focuses on the long-term sustainability of both the Basin's population and natural environment, minimizes system vulnerability, and increases system resiliency.
- Coordinated operation of Lake Powell and Lake Mead is one of multiple ways that the system can be managed. Alternative paradigms, *e.g.*, basing reservoir operations on combined reservoir or system storage, should be explored.

Structure of the 2007 Interim Guidelines and Operating Experience

The purpose of the 2007 Interim Guidelines was determined in the early stages of the NEPA process to develop the 2007 Interim Guidelines and consists of three components. As stated in Section IV of the 2007 Interim Guidelines, the purpose is to:

- ''improve Reclamation's management of the Colorado River by considering trade-offs between the frequency and magnitude of reductions of water deliveries, and considering the effects on water storage in Lake Powell and Lake Mead, and on water supply, power production, recreation, and other environmental resources;
- provide mainstream United States users of Colorado River water, particularly those in the Lower Division states, a greater degree of predictability with respect to the amount of annual water deliveries in future years,

particularly under drought and low reservoir conditions; and

• provide additional mechanisms for the storage and delivery of water supplies in Lake Mead to increase the flexibility of meeting water use needs from Lake Mead, particularly under drought and low reservoir conditions.''

Despite the additional agreements and actions undertaken since the adoption of the 2007 Interim Guidelines and ongoing processes, the four elements of the 2007 Interim Guidelines, collectively intended to meet the purpose, have remained intact. These elements are:

• *Shortage Guidelines:* Determines those conditions under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead to the Lower Division states below 7.5 million acre-feet pursuant to the Consolidated Decree.

• *Coordinated Reservoir Operations:* Defines the coordinated operations of Lake Powell and Lake Mead to provide improved operation of these two reservoirs, particularly under low reservoir conditions. As described in Section XI.G.6. of the Record of Decision, the objective of the operation of Lake Powell and Lake Mead is ''to avoid curtailment of uses in the Upper Basin, minimize shortages in the Lower Basin and not adversely affect the yield for development available in the Upper Basin.''

• *Storage and Delivery of Conserved Water:* Allows for the storage and delivery, pursuant to applicable federal law, of conserved Colorado River System and non-System water in Lake Mead to increase the flexibility of meeting water use needs from Lake Mead, particularly under drought and low reservoir conditions.

• *Surplus Guidelines:* Determines those conditions under which the Secretary may declare the availability of surplus water for use within the Lower Division states. Modifies the substance of the Interim Surplus Guidelines existing at the time the Guidelines were adopted by extending the term from 2016 to 2026 and terminating the most permissive provision.

The interim nature of the 2007 Interim Guidelines provided the opportunity to gain valuable experience in the management of Lake Powell and Lake Mead, improving the basis of understanding for future operational decisions. First implemented in 2008, Reclamation now has over 15 years of operational experience under the 2007 Interim Guidelines. Section XI.G.7.D. of the 2007 Interim Guidelines required the documentation of this experience and an evaluation of the effectiveness of the 2007 Interim Guidelines. In fulfilment of this provision, in December 2020, Reclamation published on its website ''Review of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead'' (Available at *https://www.usbr.gov/ColoradoRiverBasin/#7.D.Review*) (the 2020 7.D. Review).

The 2020 7.D. Review found that while the 2007 Interim Guidelines were effective at meeting their overall purpose, the increasing severity of the drought and prolonged period of low runoff demonstrated that the 2007 Interim Guidelines were insufficiently robust to protect reservoir storage, requiring the adoption of the DCPs and other responsive adaptive actions, both within the United States and in cooperation with Mexico.

The 2020 7.D. Review also documented important considerations for enhancing future effectiveness: (1) enhanced flexibilities and transparency for water users; (2) expanded participation in conservation and Basin-wide programs; (3) increased consideration of the linkage that occurs through coordinated reservoir operations, particularly with respect to the uncertainties inherent in model projections used to set operating conditions; and (4) more robust measures to protect reservoir levels.

Following the publication of the 2020 7.D. Review, as low snowpack and runoff conditions worsened, Reclamation undertook emergency and other drought response actions in 2021 and 2022 to protect infrastructure and operations at Glen Canyon Dam. In the November 2022 **Federal Register** notice, the Department found that due to the existence of ''extraordinary circumstances'' per Section 7.D of the 2007 Interim Guidelines, modified operating provisions may be required in order to ensure Glen Canyon Dam continues to operate under its intended design and to protect Hoover Dam operations, system integrity, and public health and safety and initiated the on-going SEIS process.

Considering the past 15 years of operating experience, the findings described in the 2020 7.D. Review, the themes expressed in response to the June 2022 **Federal Register** notice, and the information included in this NOI; Interior is interested in receiving specific input on how the purpose and the elements of the 2007 Interim Guidelines should be retained, modified or eliminated to provide greater stability to water users and the public throughout the Colorado River Basin through robust and adaptive operational guidelines. This input will be used to inform our decision on the proposed federal action, Purpose and Need, and scope of the analysis (*e.g.*, affected area, geographic scope, time horizon/term).

Elements of Process Designed to Date

In the June 2022 **Federal Register** notice, Reclamation identified that it intends to design and implement a stakeholder process for this EIS that is inclusive, transparent, and encourages meaningful engagement. Using the input received during that comment period and correspondence from Basin partners, Reclamation is in the early stages of developing certain components of its engagement and outreach approaches.

With respect to developing alternatives, input received in response to the June 2022 **Federal Register** notice suggested that Reclamation expand beyond its traditional methods of engagement and requested an inclusive process that encourages collaboration and supports the exploration of a broad range of creative operational strategies. To this end, and among other potential approaches, Reclamation is working with experts to develop a web-based tool that enables users with different levels of technical skill to explore, create, and compare potential operating strategies to enhance development of alternatives. The use of this common, accessible platform is just one part of Reclamation's stated goals of improving stakeholder and partner knowledge and engagement that supports external parties in developing strategies and provides the public greater and more timely access to relevant technical information.

In anticipation of the target Fall 2023 launch of the tool, Reclamation has convened an Integrated Technical Education Workgroup that is actively working to ensure that stakeholders are better prepared and able to engage in a robust alternatives development process. While it is valuable during this comment period to communicate ideas about the concepts and structures that could be included in alternatives, it is not necessary to submit comprehensive alternatives before the more focused period of alternatives development begins this fall.

With respect to the timing and structure of outreach during the NEPA process, Reclamation intends to develop an approach that facilitates inclusion at multiple levels and enhances tribal engagement and inclusivity. This structure for partner, stakeholder and public engagement will include individualized outreach, leverage existing groups and forums, create new

groups and forums, and provide for clear and timely communication with the public.

Through the individualized partner and stakeholder outreach, Reclamation will be available for meetings upon request and will prioritize regular, meaningful, and robust consultation with Tribal Nations. Existing forums and groups will be continued and leveraged, such as the monthly Reclamation-hosted Tribal Information Exchanges. Reclamation is also exploring options for increasing tribal involvement through the potential development of new groups and forums. In addition to timely and clear communication with the public at regular NEPA milestones, Reclamation intends to set up a broad partner-stakeholder group to ensure a full understanding of each upcoming step in the NEPA process.

As discussed in the June 2022 **Federal Register** notice, the Department is also committed to identifying processes that can complement the efforts of the International Boundary and Water Commission (IBWC) to develop post-2026 agreements that would succeed current agreements contained in Minute 323 to the 1944 Water Treaty. The Department will continue to coordinate with the IBWC to ensure Interior-led domestic planning processes are implemented in a coordinated and complementary fashion to those of the IBWC with a goal of ensuring similar timelines for informed decision making.

Public Disclosure of Comments

Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Maria Camille Touton,

Commissioner, Bureau of Reclamation.

[FR Doc. 2023–12923 Filed 6–15–23; 8:45 am]

BILLING CODE 4332–90–P

DEPARTMENT OF THE INTERIOR

Bureau of Safety and Environmental Enforcement

[Docket ID BSEE–2023–0005; EEEE500000 234E1700D2 ET1SF0000.EAQ000; OMB Control Number 1014–0015]

Agency Information Collection Activities; Unitization

AGENCY: Bureau of Safety and Environmental Enforcement, Interior.

ACTION: Notice of information collection; request for comment.

SUMMARY: In accordance with the Paperwork Reduction Act (PRA) of 1995, the Bureau of Safety and Environmental Enforcement (BSEE) proposes to renew an information collection.

DATES: Interested persons are invited to submit comments on or before August 15, 2023.

ADDRESSES: Send your comments on this information collection request (ICR) by either of the following methods listed below:

- Electronically go to *http://www.regulations.gov*. In the Search box, enter BSEE–2023–0005 then click search. Follow the instructions to submit public comments and view all related materials. We will post all comments.
- Email *kye.mason@bsee.gov*, fax (703) 787–1546, or mail or hand-carry comments to the Department of the Interior; Bureau of Safety and Environmental Enforcement; Regulations and Standards Branch; ATTN: Nikki Mason; 45600 Woodland Road, Sterling, VA 20166. Please reference OMB Control Number 1014–0015 in the subject line of your comments.

FOR FURTHER INFORMATION CONTACT: To request additional information about this ICR, contact Nikki Mason by email at *nikki.mason@bsee.gov* or by telephone at (703) 787–1607. Individuals in the United States who are deaf, deafblind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services. Individuals outside the United States should use the relay services offered within their country to make international calls to the point-of-contact in the United States. You may also view the ICR at *http://www.reginfo.gov/public/do/PRAMain*.

SUPPLEMENTARY INFORMATION: In accordance with the PRA and 5 CFR 1320.8(d)(1), all information collections require approval under the PRA. We may not conduct, or sponsor and you are not required to respond to a collection of information unless it displays a currently valid OMB control number.

As part of our continuing effort to reduce paperwork and respondent burdens, we invite the public and other Federal agencies to comment on new, proposed, revised, and continuing collections of information. This helps us assess the impact of our information collection requirements and minimize the public's reporting burden. It also helps the public understand our information collection requirements and provide the requested data in the desired format.

We are especially interested in public comment addressing the following:

(1) Whether or not the collection of information is necessary for the proper performance of the functions of the agency, including whether or not the information will have practical utility;

(2) The accuracy of our estimate of the burden for this collection of information, including the validity of the methodology and assumptions used;

(3) Ways to enhance the quality, utility, and clarity of the information to be collected; and

(4) How might the agency minimize the burden of the collection of information on those who are to respond, including through the use of appropriate automated, electronic, mechanical, or other technological collection techniques or other forms of information technology, *e.g.,* permitting electronic submission of response.

Comments that you submit in response to this notice are a matter of public record. We will include or summarize each comment in our request to OMB to approve this ICR. Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Abstract: BSEE must approve any lessee's proposal to enter an agreement to unitize operations under two or more leases and for modifications when warranted. We use the information to ensure that operations under the proposed unit agreement will result in preventing waste, conserving natural resources, and protecting correlative rights including the government's interests.

Q.3 Colorado River Reservoir Operations: Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead (October 20, 2023 – 88 FR 72535)

1976, 43 U.S.C. 1714(f), the Secretary determines that the withdrawal shall be extended.

(Authority: 43 U.S.C. 1714)

Shannon A. Estenoz,

Assistant Secretary for Fish and Wildlife and Parks.

[FR Doc. 2023–23258 Filed 10–19–23; 8:45 am]

BILLING CODE 3411–15–P

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

[RR03040000, 23XR0680A1, RX187860005004001]

Colorado River Reservoir Operations: Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

AGENCY: Bureau of Reclamation, Interior.

ACTION: Notice of availability.

SUMMARY: The Department of the Interior (Department) has issued a Scoping Summary Report on the Development of Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead. The Scoping Summary Report provides a summary of the comments received during the public scoping process and describes the Department's current, preliminary assessment of the proposed federal action, purpose and need, and scope of the environmental analysis to be included in the draft environmental impact statement (DEIS). The Department anticipates the DEIS will be published in December 2024 for public review.

ADDRESSES: The Scoping Summary Report is available on the Bureau of Reclamation's website at *https://www.usbr.gov/ColoradoRiverBasin/post2026/scoping/index.html*. Printed copies of the report are available upon request from the point of contact listed in the **FOR FURTHER INFORMATION CONTACT** section of this notice.

FOR FURTHER INFORMATION CONTACT: Amanda Erath, Colorado River Post-2026 Program Coordinator, Bureau of Reclamation, at (303) 445–2766, or by email at *crbpost2026@usbr.gov*. Please also visit the project website at *https://www.usbr.gov/ColoradoRiverBasin/post2026/index.html*. Individuals in the United States who are deaf, deafblind, hard of hearing, or have a speech disability may dial 711 (TTY, TDD, or TeleBraille) to access telecommunications relay services. Individuals outside the United States should use the relay services offered within their country to make international calls to the point-of-contact in the United States.

SUPPLEMENTARY INFORMATION: Pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended, and the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of NEPA, the Department is publishing the Scoping Summary Report as a voluntary effort to assist in public understanding of this important NEPA process. Based on the information summarized in the report, the Department is preparing a DEIS starting with the development of a reasonable range of alternatives that are technically and economically feasible and meet the purpose and need for the proposed federal action (40 CFR part 1508). Considering public input received to date, the Department's current, preliminary assessment of the proposed federal action, purpose and need, and scope of the environmental analysis to be included in the DEIS are described below and in the Scoping Summary Report.

Proposed Federal Action

The Bureau of Reclamation, acting on behalf of the Secretary of the Interior (Secretary), proposes to take action to adopt specific guidelines and coordinated reservoir management strategies to address operations of Lake Powell and Lake Mead through their full operating range. This action would provide improved predictability to all water users and managers in the Colorado River Basin by developing and adopting objective guidelines for the operation of Glen Canyon Dam and Hoover Dam to take effect when the current operating guidelines (the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead [2007 Interim Guidelines]) expire in 2026. In addition, this action is designed to provide for the sustainable management of the Colorado River system and its resources under a wide range of potential future system conditions due to a changing climate.

Based on public input, the Department anticipates the guidelines would include the following elements:

(1) Identification of circumstances under which the Secretary would allocate, reduce, or increase the annual amount of water available for consumptive use from Lake Mead to the Lower Division states (Arizona, California, and Nevada) at, below, or above 7.5 million acre-feet, pursuant to the Supreme Court Decree in *Arizona* v. *California*.[1]

(2) Coordinated operations of Lake Powell and Lake Mead, particularly under low reservoir conditions.

(3) Storage and delivery of conserved water in Lake Mead and/or Lake Powell to increase the flexibility to meet water use needs from both reservoirs, including the storage and delivery of non-system water; exchanges; and water conserved through extraordinary measures by or for tribal, agricultural, or municipal entities.

The proposed federal action allows for development of robust operating guidelines for Lake Powell and Lake Mead without precluding upstream or downstream actions needed to protect critical reservoir elevations at Lake Powell and Lake Mead, such as the following:

- Approaches that consider total system storage in all major Colorado River reservoirs and/or actual inflows to determine coordinated operations of Lake Powell and Lake Mead.
- Approaches that include opportunities for conservation, augmentation, demand management, or other water management strategies.
- Approaches that include opportunities for conservation, augmentation, demand management, or other water management strategies.
- Temporary emergency response operations at upstream Colorado River reservoirs to protect critical infrastructure at Glen Canyon Dam, so long as the project-specific operations of those reservoirs remain within their respective Records of Decision.

The Department intends that the guidelines be interim in nature and extend for at least the same duration as the 2007 Interim Guidelines (approximately 20 years), subject to further consideration during the NEPA process. Adoption of new guidelines for an interim (or limited) period provides the opportunity to gain additional experience for operating the reservoirs, thereby informing future operational and water management decisions.

Recognizing additional authorities may be developed, it is the intent of the Department to adopt and implement the guidelines in a manner consistent with the Law of the River.[2] It is also the

[1] The Department intends to meet any consultation requirements identified in Article II(B)(3) of the Supreme Court Decree in *Arizona* v. *California* through the ongoing NEPA process initiated by the **Federal Register** Notice of June 16, 2023 (88 FR 39455–39458) and the annual implementation of guidelines developed through this process.

[2] The treaties, compacts, decrees, statutes, regulations, contracts, and other legal documents

Continued

intent of the Department that the guidelines be used to implement the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs Pursuant to the Colorado River Basin Project Act of September 30, 1968 (LROC).

Purpose and Need for the Proposed Federal Action

In accordance with NEPA implementing regulations, a statement of purpose and need is required in an EIS to explain why the agency is proposing the action. The ''need'' for the action may be described as the underlying problem or opportunity to which the agency is responding with the action; the ''purpose'' may refer to the goal or objective that the agency is trying to achieve (43 CFR 46.420).

The proposed federal action is needed for the following reasons:

- *The Secretary is legally required to coordinate operations of Colorado River reservoirs:* The Colorado River Basin Project Act of 1968 directs the Secretary to propose criteria for the coordinated long-range operation of Colorado River reservoirs. In compliance with this obligation, the LROC were developed and adopted by the Secretary in 1970. The LROC provide general narrative guidance regarding Lake Powell and Lake Mead operations but does not contain specific, objective criteria to guide annual operations. To address this inadequacy, the 2007 Interim Guidelines were developed to provide objective criteria used by the Department to implement the LROC. These guidelines have provided predictability needed by the entities that receive Colorado River water to better plan for and manage available water supplies from the Colorado River and other sources.
- *2007 Interim Guidelines are expiring:* Current operational guidelines expire during the 2026 operating year. The Department has determined that specific, objective operational guidelines are important to provide improved predictability and should be established for another interim period beyond 2026.
- *2007 Interim Guidelines have not sufficiently reduced risk:* Based on operational experience since 2007, the current guidelines are not robust enough to manage in a way that is sufficiently protective of the resources dependent on the Colorado River. Despite near-continuous drought-response actions in recent years, low-reservoir conditions have persisted and new infrastructure risks at Glen Canyon Dam have arisen. More robust and adaptive guidelines are needed for the efficient and sustainable management of the major mainstream Colorado River reservoirs and system resources.
- *Imbalance between water supply and demand will be exacerbated by increasingly likely low-runoff conditions:* Climate science indicates the Colorado River Basin is experiencing climate-change induced aridification and that long-term and sustained drought and low-runoff conditions should be expected in the future. These conditions will exacerbate the now widely recognized imbalance between water supply and demand in the Colorado River Basin. Robust and flexible guidelines are needed to manage the Colorado River system and its resources under a broad range of potential future hydrologic conditions.
- *Expanded and innovative use of conservation is needed:* Recognizing the anticipated future low-runoff conditions in the Colorado River Basin, the Department has also determined a need for guidelines that provide Colorado River water users, including Basin Tribes, expanded opportunities to conserve, store, and take subsequent delivery of water in and from Lake Mead and/or Lake Powell. The guidelines should also support and integrate future efficiency improvements and opportunities for augmentation.
- *Addressing tribal concerns regarding Colorado River Basin management is needed:* Basin Tribes have expressed concern that the current approach to Colorado River water management is insufficient to address the range of interests, needs, and fundamental rights of the Basin Tribes. The Department has determined a need for guidelines that provide flexibility and predictability for Basin Tribes to remain able to benefit from their water rights and have an opportunity to participate in voluntary conservation programs.

The purpose for the proposed federal action is to:

- update and expand management guidelines for Colorado River reservoirs, particularly for Lake Powell and Lake Mead;
- provide Colorado River water users, a greater degree of predictability with respect to the amount of annual water available in future years under anticipated increasing variability, low runoff and low reservoir conditions;
- provide additional mechanisms for the conservation, storage and delivery of water supplies in Colorado River reservoirs;
- provide new or enhanced opportunities for Basin Tribes to benefit from their water rights; and
- provide flexibility to build resilience and accommodate future needs and growth that are supported by Colorado River water supplies, including the integration of unquantified tribal water rights once they are resolved.

DEIS Approach

The DEIS will consider the best scientific information currently available; actual operating experience since 2007; updated information on infrastructure considerations at Glen Canyon Dam and Hoover Dam; trade-offs between the frequency and magnitude of reductions in water deliveries; mechanisms to encourage water conservation, efficiency improvements, and augmentation; and the effect of water storage in Lake Powell and Lake Mead on water supply, power production, recreation, environmental resources, cultural resources, and other relevant resources and factors.

The geographic scope of the environmental analysis in the DEIS is dependent upon the range of alternatives developed in the DEIS and therefore will be determined later in the NEPA process.

Next Steps

With this Notice, the Department is transitioning to the next phase of the NEPA process, which is to develop alternatives for analysis in the DEIS. Reclamation has developed state-of-the-art web-based tools to encourage and facilitate stakeholder collaboration during this phase and intends to deploy these tools in the early stages of this phase in the fall. It is the Department's intent that these tools support the exploration and development of a broad range of reasonable alternatives and foster collaborative consensus-based approaches to alternative development.

Maria Camille Touton,

Commissioner, Bureau of Reclamation.

[FR Doc. 2023–23127 Filed 10–19–23; 8:45 am]

BILLING CODE 4332–90–P

and agreements applicable to the allocation, appropriation, development, exportation, and management of the waters of the Colorado River Basin are often referred to as the ''Law of the River.'' There is no single, universally-agreed upon definition of the ''Law of the River,'' but it is useful as a shorthand reference to describe this longstanding and complex body of legal agreements governing the Colorado River.

Q.4 Environmental Impact Statements; Notice of Availability (U.S. Environmental Protection Agency, Federal Register, January 16, 2026; 91 FR 2131; FR Doc. No. 2026-00844)

The Draft Environmental Impact Statement for the Post-2026 Colorado River Reservoir Operations was filed with the U.S. Environmental Protection Agency on January 12, 2026. The Environmental Protection Agency published the Notice of Availability in the Federal Register on January 16, 2026 (91 FR 2131), initiating the 45-day public review and comment period pursuant to 40 CFR 1506.10.

TABLE 1—LIST OF RCRA WASTE CODES APPROVED FOR INJECTION—Continued

U128	U129	U130	U131	U132	U133	U134	U135	U136	U137	U138	U140
U141	U142	U143	U144	U145	U146	U147	U148	U149	U150	U151	U152
U153	U154	U155	U156	U157	U158	U159	U160	U161	U162	U163	U164
U165	U166	U167	U168	U169	U170	U171	U172	U173	U174	U176	U177
U178	U179	U180	U181	U182	U183	U184	U185	U186	U187	U188	U189
U190	U191	U192	U193	U194	U196	U197	U200	U201	U202	U203	U204
U205	U206	U207	U208	U209	U210	U211	U213	U214	U215	U216	U217
U218	U219	U220	U221	U222	U223	U225	U226	U227	U228	U234	U235
U236	U237	U238	U239	U240	U243	U244	U246	U247	U248	U249	U271
U278	U279	U280	U328	U353	U359	U364	U367	U372	U373	U387	U389
U394	U395	U404	U409	U410	U411						

Electronic Access. You may access this **Federal Register** document electronically from the Government Printing Office under the "**Federal Register**" listings at *https://www.govinfo.gov/app/collection/FR/.*

Tera Fong,

Director, Water Division.

[FR Doc. 2026–00776 Filed 1–15–26; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

[FRL OPRM–FAD–205]

Environmental Impact Statements; Notice of Availability

Responsible Agency: Office of Federal Activities, General Information 202–993–3272 or *https://www.epa.gov/nepa.*

Weekly receipt of Environmental Impact Statements (EIS)

Filed January 5, 2026 10 a.m. EST

Through January 12, 2026 10 a.m. EST

Pursuant to CEQ Guidance on 42 U.S.C. 4332.

Notice: Section 309(a) of the Clean Air Act requires that EPA make public its comments on EISs issued by other Federal agencies. EPA's comment letters on EISs are available at: *https://cdxapps.epa.gov/cdx-enepa-II/public/action/eis/search.*

EIS No. 20250180, Final, USAF, NV, Master Plan and Installation Development at Nellis Air Force Base, Nevada, *Contact:* Daniel Fisher 210–925–2738.

EIS No. 20250181, Draft Supplement, BLM, CA, Central Coast Field Office Oil and Gas, Leasing and Development, California, *Comment Period Ends:* 03/06/2026, *Contact:* Sarah Mathews 831–582–2257.

EIS No. 20250182, Draft Supplement, BLM, CA, Bakersfield Field Office Oil and Gas Leasing and Development, California, *Comment Period Ends:* 03/06/2026, *Contact:* Sarah Mathews 661–391–6145.

EIS No. 20250183, Final, FTA, TX, Austin Light Rail Phase 1 Project, *Contact:* Terence Plaskon 817–978–0573.

Under 23 U.S.C. 139(n)(2), FTA has issued a single document that consists of a final environmental impact statement and record of decision. Therefore, the 30-day wait/review period under NEPA does not apply to this action.

EIS No. 20250184, Draft, BR, CO, Post-2026 Colorado River Reservoir Operations, *Comment Period Ends:* 03/02/2026, *Contact:* KayLee Nelson 702–293–8073.

Dated: January 12, 2026.

Nancy Abrams,

Deputy Director, Federal Activities Division.

[FR Doc. 2026–00844 Filed 1–15–26; 8:45 am]

BILLING CODE 6560–50–P

EQUAL EMPLOYMENT OPPORTUNITY COMMISSION

Commission Meeting—Sunshine Act Notice

TIME AND DATE: Thursday, January 22, 2026, 10:00 a.m. Eastern Time.

PLACE: The meeting will be held at the Jacqueline A. Berrien Training Center, 131 M Street NE, Washington, DC 20507. The meeting will also be held as a listen-only audio dial-in by telephone. The public may attend in person or connect to the audio-only dial-in by following the instructions that will be posted on *www.eeoc.gov* at least 24 hours before the meeting. ASL services will be available for those attending the meeting in person and a closed captioning link will be posted on our website prior to the meeting.

If you wish to attend the meeting in person, you must email *commissionmeetingcomments@eeoc.gov* to register by providing your name as it appears on your driver's license or other government-issued identification at least 24 hours prior to the meeting. You will be asked to show your ID upon arrival.

STATUS: The meeting will be open to the public.

MATTERS TO BE CONSIDERED: The following item will be considered at the meeting:

- Rescission of Enforcement Guidance on Harassment in the Workplace
- Resolution Concerning the Commission's Authority to Commence or Intervene in Litigation
- Obligation of Funds Requiring Commission Approval

Note: In accordance with the Sunshine Act, the public will be able to observe the Commission's deliberations and voting. (In addition to publishing notices on Commission meetings in the **Federal Register**, the Commission also provides information about Commission meetings on its website, *www.eeoc.gov* and provides a recorded announcement one week in advance of future Commission meetings.) Public observation does not include participation. Observers seeking to take still photographs, video, or audio recordings of the meeting must seek permission by contacting the Executive Secretariat at *commissionmeetingcomments@eeoc.gov* at least 24 hours before the meeting to discuss the manner of recording and ensure it does not interfere with the meeting.

Please telephone (202) 921–2705, or email *commissionmeetingcomments@eeoc.gov* at any time for information on this meeting.

CONTACT PERSON FOR MORE INFORMATION: Raymond Windmiller, Executive Officer, (202) 921–2705.

Date: January 14, 2026.

Raymond D. Windmiller,

Executive Officer, Executive Secretariat.

[FR Doc. 2026–00900 Filed 1–14–26; 4:15 pm]

BILLING CODE 6570–01–P

FEDERAL PERMITTING IMPROVEMENT STEERING COUNCIL

Agency Information Collection Activities: Proposed Collection; Comment Request

AGENCY: Federal Permitting Improvement Steering Council.

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Appendix R

Response to Public Comment

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Acronyms and Abbreviations

	Full Phrase
A.R.S.	Arizona Revised Statutes
BA	biological assessment
Basin	Colorado River Basin
BCPA	Boulder Canyon Project Act
BO	biological opinion
CAP	Central Arizona Project
CFR	Code of Federal Regulations
CRBPA	Colorado River Basin Project Act of 1968
CRSP	Colorado River Storage Project
CRSS	Colorado River Simulation System
CU&L	consumptive use and loss
Department	Department of the Interior
DOI NEPA Handbook	United States Department of the Interior Handbook of National Environmental Policy Act Implementing Procedures
DSPR	Dam Safety Priority Rating
EIS	environmental impact statement
ESA	Endangered Species Act
FWS	United States Fish and Wildlife Service
GCPA	Grand Canyon Protection Act of 1992
HFE	high-flow experiment
IBWC	International Boundary Water Commission
ICS	Intentionally Created Surplus
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Lower Basin	Lower Colorado River Basin
LROC	Long-Range Operating Criteria
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
Mexico	United Mexican States
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
PA	Programmatic Agreement

Reclamation	Bureau of Reclamation
ROD	Record of Decision
UCRC	Upper Colorado River Commission
Upper Basin	Upper Colorado River Basin
U.S.	United States
U.S.C.	United States Code

Appendix R. Response to Public Comment

R.1 Introduction

A Notice of Availability of the Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead Draft Environmental Impact Statement (EIS) was published in the Federal Register on January 16, 2026, which kicked off a 45-day public review and comment period that ended March 2, 2026. The Draft EIS was available on the Bureau of Reclamation (Reclamation) project website along with an interactive tool designed to allow for easy comparison of impact analysis figures within the Draft EIS. This appendix provides an overview of the public review and comment process, how Reclamation addressed the comments, and details the grouping of similar comments into common themes with responses from Reclamation.

R.2 Summary of the Public Comment Period and Public Comment Analysis Process

Reclamation received 18,153 submissions during the Draft EIS comment period. Of the submissions, 7 were from state government entities, 23 from tribes, 4 from federal agencies, 28 from non-government organizations, 76 from local entities, 3 from academic or research institutions, 5 from elected officials, 21 from resource sector or business interests, and the remainder were from individuals. Twenty-three form letters were identified; 11,992 submittals had identical text to one of the 23 form letters and 5,298 had unique text in addition to the form letter text. Fifty-two submittals were noted as duplicate and only reviewed once. Unique submissions are available on the https://www.usbr.gov/uc/DocLibrary/Memos/20240326-EstablishmentInterimOperatingGuidanceGlenCanyonDamLowReservoirLevels-TechnicalDecisionMemo-508-TSC.pdf, and all public comments are retained in the project record.

All submissions were recorded and reviewed to identify substantive comments. A comment was considered substantive if it met one or more of the following criteria (United States [U.S.] Department of the Interior Handbook of National Environmental Policy Act Implementing Procedures [DOI NEPA Handbook 2026]):

- Questioned, with a reasoned basis related to the analysis, the accuracy of information in the EIS.
- Questioned, with a reasoned basis related to the analysis, the adequacy of, methodology for, or assumptions used for the analysis.
- Presented new information relevant to the analysis.
- Presented reasonable alternatives or issues outside those analyzed in the EIS.
- Presented relevant additional issues for analysis in the EIS.
- Prompted potential changes or revisions to one or more of the alternatives.

When multiple submissions had identical text, a form letter was established and reviewed once. The remaining copies of that submission were counted but not reviewed separately. If a submission had identical text but included additional unique text, the additional text was reviewed for substantive comments.

The comments received encompassed a wide array of policy and environmental issues, with many submissions addressing substantially similar subject matter or offering overlapping input. Given the high volume of substantive comments, and in accordance with Department guidance (DOI NEPA Handbook 2026, Appendix 1 Section 1), substantive comments were compiled in a database and organized into themes to allow similar comments to be reviewed and addressed collectively. This appendix presents those themes and Reclamation's responses. Using a theme-based approach provides a clear representation of the breadth and character of public input on each topic and offers greater context than a one-to-one comment-response format by reducing repetition and presenting comprehensive, synthesized responses. A table of contents (**Contents**, R-i) is provided to guide readers to specific subject areas reflecting the common themes and recurring issues identified in the comments received.

The themes summary and responses below were developed following the public comment period on the Draft EIS and during the development of the Final EIS. Many of the theme summaries and their associated comments led to changes in the Final EIS. Reclamation addressed comments consistent with the requirements of the DOI NEPA Handbook 2026. These requirements included but were not limited to analyzing a reasonable range of alternatives; using the best available scientific data; and not covering speculative analysis or analysis of impacts outside of the agency's control. In addition, this EIS does not attempt to interpret specific questions related to the Law of the River.

R.3 Public Comment Themes and Responses

R.3.1 Secretarial Authorities

Theme Summary

Commenters raised concerns that the Draft EIS does not adequately or accurately describe the Secretary's authorities and does not clearly identify which operational elements would require new or additional authority (e.g., statutory changes, new or modified Records of Decision (RODs), or interstate agreements). Commenters raised differing and conflicting interpretations of Secretarial authority and the Law of the River. For example, commenters in the Upper Colorado River Basin (Upper Basin) emphasize limits on Reclamation's role in administering Upper Basin apportionments, while Lower Colorado River Basin (Lower Basin) commenters urge broad authority to protect infrastructure and ensure Compact compliance, including through operation of Colorado River Storage Project (CRSP) facilities. Other areas of conflicting comments include how to distribute shortages in the Lower Basin, emergency authorities, and certain reservoir operations. These comments frequently fail to acknowledge that there are many conflicting legal views on Colorado River topics that have remained unresolved for the past century, and the comments then assert that the Secretary's decision not to endorse the commenter's particular view of a contested Colorado River legal theory is a flaw in the National Environmental Policy Act (NEPA) analysis.

Response

The Secretary of the Interior possesses broad authorities for the management and operation of the Colorado River System under applicable federal law and the Law of the River. While differing interpretations exist regarding the scope and application of certain authorities, this EIS is not intended to resolve or opine on such legal interpretations. Reclamation recognizes that implementation of certain operational elements analyzed in this EIS may or may not require additional authorities, and the Department of the Interior (Department) intends to implement any adopted guidelines in a manner consistent with applicable law and the Law of the River.

Particularly in the current context where Colorado River stakeholders have been unable to resolve disagreements over key aspects of applicable legal authorities, limiting the inclusion of operational elements in this EIS that are solely within an as yet nonexistent universal agreement regarding legal authority would unnecessarily constrain the reasonable range of alternatives and could limit the Department's ability to evaluate potential tools that could be developed or could be needed to address future operational and water supply challenges in the Colorado River Basin (Basin).

The EIS discusses additional authorities that may or may not be needed to implement the Preferred Alternative, and the Department may also wish to consider specific identification of authorities needed to implement future operations that could be the result of a consensus proposal.

R.3.2 1922 Colorado River Compact Compliance

Theme Summary

Commenters expressed differing views regarding 1922 Compact compliance and how 1922 Compact-related obligations between the Upper Basin and Lower Basin should be reflected in the range of alternatives and impact analysis. Lower Basin commenters stated that the Draft EIS does not analyze operations that are aligned with the Lower Basin interpretation of Compact compliance, including CRSP Upper Initial Unit operations, and that the Lower Basin would be disproportionately affected. Some commenters also expressed that the Draft EIS does not clearly articulate whether, or how, assumptions regarding 1922 Compact interpretations account for United Mexican States (Mexico)-related delivery obligations, Lower Basin tributaries, surplus determinations, or the extent to which Lake Powell releases should reflect those considerations. These comments generally seek greater integration of 1922 Compact compliance considerations into the alternatives and explanation of how differing interpretations are reflected in the analysis.

Response

Section 602 of the Colorado River Basin Project Act of 1968 (CRBPA) required the Secretary to propose and adopt criteria for the coordinated long-range operation of the reservoirs constructed and operated under the authority of the CRSP Act of 1956, the Boulder Canyon Project Act of 1928 (BCPA), and the Boulder Canyon Project Adjustment Act. The Secretary adopted such Long-Range Operating Criteria (LROC) in 1970 and has been operating the Colorado River consistent with the LROC since that time. The LROC and Guidelines (2001, 2007) were adopted in a manner designed to comply with the 1922 Compact.

As with the 2001 Interim Surplus Guidelines and the 2007 Interim Guidelines, it is the Department's intention that post-2026 guidelines be used to implement the LROC, and the Department is not modifying the LROC at this time. Further, with post-2026 guidelines, the Department is not interpreting the legal meaning of the 1922 Colorado River Compact or resolving differing interpretations by Basin States, Basin Tribes, and other stakeholders.

Reclamation will follow all relevant provisions of federal law to implement the proposed federal action, including relevant provisions of the Law of the River. Reclamation recognizes that, under Article II(2) of the LROC, the "objective shall be to maintain a minimum release of water from Lake Powell of 8.23 [million acre-feet (maf)]." Reclamation also recognizes that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted. To inform Basin partners and stakeholders of the relevant considerations for the proposed federal action, Reclamation identified and published any annual deficits below the objective release of 8.23 maf, as well as relevant 10-year metrics of particular interest at Lee Ferry, such as the 10-year consecutive aggregate flow, along with any deficit in the 10-year consecutive aggregate flow (such as, any deficit from 82.5 maf and 75 maf), see **Section 1.8.2.2**, for further discussion.

While the LROC are "administered consistent with applicable federal laws," Reclamation intends and has expressly noted in the Final EIS that releases from Lake Powell pursuant to the LROC or any adopted guidelines "shall not prejudice the position of either the Upper or Lower Basin interests with respect to the required deliveries at Lee Ferry pursuant to the Colorado River Compact." (Article II(5) of the LROC), see **Section 1.8.7**, for further discussion.

R.3.3 Upper Initial Unit Operations

Theme Summary

Upper Basin stakeholders generally noted that the CRSP Upper Initial Unit use should not be included in alternatives as it is not in geographic scope and that inclusion of CRSP Upper Initial Units exceeds Secretarial authorities. Conversely, Lower Basin stakeholders generally noted that the alternatives should include more CRSP Upper Initial Unit use, including operations outside existing RODs for Compact compliance. Additionally, commenters noted that analysis of impacts from CRSP Upper Initial Unit operations is not adequate.

Response

Given that the description of the proposed federal action has, from the outset, contemplated the use of CRSP Upper Initial Units, it is appropriate to include the effects of these CRSP Upper Initial Unit releases on Lake Powell in the analysis. The range of CRSP Upper Initial Unit operations is within existing federal authorities and within the scope of their respective existing RODs, and these operations have therefore already undergone NEPA analysis. This EIS focuses on alternatives for changing operations within the geographic scope identified in **Section 1.5.1** of the Final EIS, which begins at full pool of Lake Powell and extends downstream along the mainstream Colorado River floodplain to the Southerly International Boundary with Mexico. There is no NEPA requirement that would require a broader geographic scope for this effort. Any operation of CRSP Upper Initial Units outside of RODs would occur only under emergency circumstances. While the Secretary will

consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the CRSP Upper Initial Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes stated in the CRSPA. Such operations are not addressed in this NEPA analysis. If emergency conditions arise, any operational decisions will be made at that time based on the then-current conditions with appropriate levels of analysis. Proactively changing operations of CRSP Upper Initial Units beyond their existing RODs, along with other connected actions, is not part of the proposed action and can be analyzed through separate NEPA processes if warranted. The alternatives represent a reasonable range of releases from CRSP Upper Initial Units, and the level of analysis provided is appropriate for this EIS. For discussion of issues related to Compact compliance, see **Section R.3.2**, 1922 Colorado River Compact Compliance.

R.3.4 Upper Basin Demands, Shortage, and Conservation

Theme Summary

Commenters raised concerns about assumptions related to Upper Basin demands, the treatment of hydrologic shortage in the Upper Basin, and the nature and feasibility of Upper Basin conservation measures.

Response

With respect to the Upper Basin depletion demands, it is important to distinguish between the depletion demands input to the model and the Upper Basin depletion calculated by the model. The Upper Basin baseline depletion demands used as input to the Colorado River Simulation System (CRSS) model were developed from the Upper Colorado River Commission's (UCRC) updated 2016 Depletion Demand Schedule (revised in 2022). In coordination with the Upper Division States, the UCRC developed decadal projections of depletions by sector at the state level to support long-term planning efforts. These projections represent anticipated demand under ideal hydrologic and economic conditions and are not supply-limited. The Arizona portion of the Upper Basin demand schedule was developed by Reclamation based primarily on the 2018 Tribal Water Study demand schedules and is primarily comprised of Navajo Nation uses. Collectively, these baseline demands represent the current best available data for input to CRSS.

In conjunction with incorporating this updated depletion demand schedule, CRSS was updated and calibrated to better characterize the variability and range of modeled Upper Basin depletions and to reduce streamflow bias during a historical verification period. **Figures I-1** to **I-6** in the Final EIS demonstrate that, although the depletion demands input to the model exceed historical depletion (i.e. consumptive uses and losses [CU&L]) and increase over time, Upper Basin modeled depletion is constrained by water availability (i.e., varying hydrologic conditions) and is therefore comparable to observed historical use. In the model, calibration was achieved by adjusting the water available for diversion by agricultural users. As a result, modeled depletions are better represented volumetrically (on a reach-by-reach basis in CRSS) but may not reflect actual sector- and water user-level depletions—which depend on demand, geographic location (e.g., tributary versus mainstem), priority, and water availability, and are not represented at the CRSS model scale.

With respect to hydrologic shortage, the difference between the Upper Basin depletion demand schedule input to CRSS and the Upper Basin depletion calculated by the model represents modeled hydrologic shortage given water availability. **Figure I-7** shows the Upper Basin modeled hydrologic shortage calculated using CRSS from 2027 to 2060. As noted above, while basin-wide Upper Basin modeled hydrologic shortage is better represented volumetrically due to model calibration, the volume does not account for important nuances that affect Upper Basin hydrologic shortage, such as water user-specific demand, geographic location (e.g., tributary versus mainstem), priority, and water availability. However, it is reasonable for the EIS analysis to represent the reality that, in many years, depletions by some Upper Basin users are constrained by available supply in their respective locations. For a historical representation of Upper Basin hydrologic shortage, refer to Reclamation's *Upper Colorado River System Consumptive Uses and Losses Report*, available online.

Refer to **Appendix L**, Upper Basin States Depletion Schedules, for additional information on the Upper Basin depletion schedules, **Appendix A,** CRSS Model Documentation, for CRSS calibration, and **Appendix I,** Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead, for additional information on the operational impacts of varying Upper Basin demands on Lake Powell and Lake Mead. Reclamation will continue to work with the UCRC and the Upper Division States and other stakeholders to update the depletion demand schedules as appropriate.

With respect to the nature and feasibility of Upper Basin conservation measures, the viability of the proposed conservation programs is unknown. For purposes of environmental impact analysis, and to analyze the full impacts of the alternatives, it was assumed that the voluntary conservation targets would be achieved. Because the specific entities that might participate in a voluntary conservation program are not known, additional analysis of impacts on specific entities is not possible.

Modeled Upper Basin conservation spans a broad range of volumes and operational approaches, some of which vary based on hydrologic conditions. **TA 3**, Hydrologic Resources, includes a sensitivity analysis comparing the impacts of including (conservation on) and excluding (conservation off) conservation activities within the alternatives, illustrating the range of impacts associated with varying levels of Upper Basin conservation.

R.3.5 LROC Implementation

Theme Summary

Commenters raised concerns regarding implementation of the 1970 LROC, particularly the role and interpretation of the "objective" to "maintain a minimum release of 8.23 maf" annually from Lake Powell and the calculation of the 602(a) storage. Some commenters asserted that the No Action Alternative improperly treats 8.23 maf as a fixed annual release requirement, while others contended that the Basic Coordination Alternative improperly allows releases below 8.23 maf. Additional comments asserted that 602(a) storage is calculated incorrectly or inconsistently with the LROC and related operating criteria.

Response

The Secretary of the Interior adopted LROC in 1970 in compliance with Section 602 of the CRBPA (Public Law 90-537). The narrative provisions of LROC are used to inform determinations with respect to storage reservoirs in the Basin under the No Action Alternative. While LROC provides that 8.23 maf is an objective for a minimum annual release, a reasonable representation of future hydrologic conditions, including releases below 8.23 maf, is necessary for comparison under the Basin Coordination Alternative.

Among other provisions, the LROC provide that "the objective shall be to maintain a minimum release of water from Lake Powell of 8.23 maf for that year." Reclamation recognizes that entities in the Basin have different legal positions regarding how this provision incorporates other Law of the River elements to determine annual releases. The Secretary has expressly recognized that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted (Norton 2005). The LROC expressly note that releases from Lake Powell pursuant to the LROC or any adopted guidelines "shall not prejudice the position of either the Upper or Lower Basin interests with respect to the required deliveries at Lee Ferry pursuant to the Colorado River Compact."

Comments received on the Draft EIS illustrate a longstanding dispute between the Upper Basin and the Lower Basin about whether annual releases can be lower than 8.23 maf. This dispute was not resolved during the period from 1970-2007 when the LROC was the sole basis for coordinated reservoir operations, and conditions never presented themselves during this period that caused the Secretary to make a decision about releases lower than the LROC's 8.23 maf objective. Instead, poor hydrology in the early 2000s prompted development of the 2007 Guidelines that adopted objective criteria for annual release volumes that implemented LROC's narrative criteria concerning release objectives. This NEPA process builds on the approach of the 2007 Interim Guidelines to adopt new, objective criteria to implement LROC. The EIS accordingly applies LROC provisions consistently for purposes of evaluating environmental impact and does not resolve differing legal interpretations raised by commenters. No additional analysis is recommended.

Despite the operational challenges due to prolonged drought, the release from Lake Powell over the term of the 2007 Interim Guidelines has met or exceeded the minimum objective release of 8.23 maf in 13 out of 19 years, and has averaged 8.5 maf over the 2008-2026 period. Going forward, the Department recognizes the continued importance of operating to achieve a minimum objective release of 8.23 maf, but meeting this objective release has been and will be increasingly difficult in a constrained system of low reservoir elevations, declining river flows, and the need to protect the operational reliability of Glen Canyon Dam.

R.3.6 Glen Canyon Dam and Hoover Dam Infrastructure

Theme Summary

Commenters asserted that the Draft EIS does not adequately address infrastructure risks at Glen Canyon Dam and Hoover Dam. Specifically, commenters requested that the EIS consider potential infrastructure fixes, repairs, or physical modifications as part of the alternatives, and provide

additional information regarding ongoing or planned processes to address known and emerging infrastructure constraints.

Theme Response

The Department discussed the operational risks at Glen Canyon Dam in **Section 1.8.4.1** of the Final EIS, which is based upon the current operational guidance for the dam (Reclamation 2024), and expressly states that low reservoir conditions have brought to light risks that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs.

Specific infrastructure modifications are not currently contemplated as components of individual alternatives within the EIS, since pursuing them would not be dependent on adopting specific operational guidelines. Infrastructure modifications are outside the scope of the EIS because they would constitute an action separate from operation of Glen Canyon and Hoover Dams. Reclamation is analyzing feasible paths for reducing risks and impacts related to infrastructure. Should Reclamation move forward with infrastructure modifications, it would need to complete additional studies, seek funding, and undertake separate NEPA compliance. Future operations would account for infrastructure modifications.

With respect to Glen Canyon Dam infrastructure specifically, which impacts releases to the Lower Basin, some alternatives include releases when Lake Powell elevation is below the critical threshold of 3,490 feet. Therefore, the possibility of releases at these low elevations is captured in the EIS. Operational actions within the scope of the EIS, such as additional releases from CRSP Upper Initial Units to release additional water if needed to protect critical infrastructure at Glen Canyon Dam, are also described. Furthermore, infrastructure modifications to access water stored below 3,490 feet would have a relatively insignificant impact on releases long-term because the volume of water stored below this elevation is relatively small—less than 3.743 maf—and would effectively only be able to be released downstream once.

R.3.7 Lower Basin Shortage and Use

Theme Summary

Comments on Lower Basin shortage and use covered topics associated with the interaction between conservation and shortage, the total volumes of shortage specified in the alternatives, the distributions of shortage within the Lower Basin, including dead pool-related reductions, preferences on allowable uses in the Lower Basin, and the quantification and modeling of Lower Basin demands. Each topic is summarized and responded to in the following sub-sections.

Theme Response

The EIS analyzed a broad range of release, delivery, shortage, and distribution options for Colorado River operations. Modeling assumptions regarding the distribution of Lower Basin shortages and Lower Basin conservation activities were developed to enable the analysis of the environmental effects across alternatives and to provide for a comparison of impacts given different methodologies of distributing shortages. These modeling assumptions are not intended to interpret specific

provisions of the Law of the River or the state law appropriation process of any of the Basin States. Responses to each topic are included below.

R.3.7.1. Interaction between Conservation and Shortage

Summary

Comments suggested that there should be a focus on conservation before shortages are implemented, and that conservation should not be allowed to reduce or satisfy required shortages.

Response

Voluntary conservation through Intentionally Created Surplus (ICS) and system conservation agreements has been a critical tool in the Lower Basin, helping reduce system risk and avoid involuntary reductions. Since 2012, approximately 10.4 maf of additional voluntary conservation has been created by the Lower Basin and Mexico, equivalent to approximately 150 feet in Lake Mead elevation. While future system conservation agreements funded by the federal government are subject to the availability of future federal funding, it is reasonable to expect that ICS-like tools will continue to be used in the Lower Basin to manage and may reduce the likelihood of large-scale mandatory reductions. Therefore, all action alternatives in the Draft EIS, except for the Basic Coordination Alternative (which assumes no future agreements are reached), included future conservation pools in Lake Mead. The different action alternatives also included a range of assumptions related to the ability to use conserved water to meet or offset required reductions. Additional details on Lower Basin Conservation are included in **Section R.3.8**, Lower Basin Conservation and Storage and Delivery of Conserved System and Non-System Water.

R.3.7.2. Total Shortage Volume

Summary

Comments spanned a wide range, from total shortages being insufficient to protect critical elevations at Lake Powell and Lake Mead (largely focused on the No Action and Basic Coordination alternatives), to the proposed shortage volumes being unacceptably high when considering potential socioeconomic impacts.

Response

The Draft EIS analyzed a range of shortage volumes up to 4 maf/year and reported "dead pool related reductions" – the reductions that occurred in modeling due to the physical limitations of infrastructure when Lake Mead is near or at dead pool. The maximum specified shortage volume was sufficiently protective under most conditions. For example, the Maximum Operational Flexibility Alternative, which included shortages up to 4 maf/year, avoided dead pool-related reductions in nearly 100 percent of years in dry conditions and 79 percent of years in critically dry conditions. Given the extremely dry streamflow conditions analyzed, which extend well beyond droughts in the observed historical record, it was not expected that shortages would be protective under all hydrologic conditions. See **Appendix F**, Approach to Hydrologic Uncertainty, for more details. Comparing the maximum specified shortage in each alternative and the associated dead pool-related reductions provides information on the tradeoffs between higher/lower shortages and higher/lower dead pool-related reductions. The maximum specified shortage volume analyzed was

4.0 maf while the maximum dead pool-related reduction analyzed was 6.54 maf. Reclamation acknowledges that there would be socioeconomic and other impacts from shortages, which were analyzed and disclosed in the Draft EIS, and which are unavoidable under any combination of alternatives.

R.3.7.3. Distribution of Shortage within the Lower Basin

Summary

An almost universal comment received was that entities other than the commenting entity should bear shortage reductions, or that the commenting entity should not be shorted at all or as much. There were additional variants on this topic, about which commenters held opposing views, including that a distribution of shortage other than by priority is illegal, that the existing priority distribution systems are not equitable, and that the priority system no longer serves the residents of the Lower Basin. Related comments on dead pool-related reductions were conflicting; some commenters recommended distributing reductions pro rata, while others recommended distributing them by priority, and still others identified specific users that should not be affected by dead pool-related reductions. Comments also identified that neither the population and land use nor the socio-economic impacts of dead pool-related reductions were analyzed.

Response

The Draft EIS analyzed shortages according to several different methodologies to provide a range of impacts across resources for the different shortage distributions. In accordance with the Consolidated Decree, the CRBPA, and other key provisions of the Law of the River, the Secretary has the authority to declare and allocate shortages to the Lower Division States. Some explicit guidance is given by the Supreme Court and Congress with regard to how shortages would be allocated according to priority, and additional detail is based on intra-state priority systems including as established by law and contract, and federal water delivery contracts executed pursuant to Section 5 of the BCPA. The methodologies incorporated this guidance and variations in distribution among users to encompass potential shortage sharing agreements. Modeling assumptions with respect to the distribution of shortages to the Lower Division States and Mexico were necessary in order to analyze potential impacts on hydrologic and other environmental resources.

The Draft EIS specifically includes a methodology that is inconsistent with the Decree and CRBPA (i.e. distribution of reductions pro rata to all entities that receive water from the mainstream in the Lower Basin pursuant to the Decree). Reclamation acknowledges that it would need additional agreements or other legal authority to implement any operations that are inconsistent with the Decree and CRBPA. But Reclamation has also determined that, based on public input received during the scoping and alternative development phases of the NEPA process, analysis of these operations will present a broader range of operations and impacts for agency and stakeholder consideration, review, and input, and will foster meaningful and informed decision-making among Reclamation and Basin stakeholders.

Reclamation's modeling assumptions for the distribution of dead pool-related reductions were documented in **Appendix A,** CRSS Model Documentation, and are meant for modeling purposes

only as no alternative included any specific criteria or methodology for the distribution of dead pool-related reductions. This distinction has been clarified in **Appendix A**.

While the population, land use, and socio-economic impacts of dead pool-related reductions were not specifically analyzed in the Draft EIS because they fall outside federal control, the range of modeled shortages under the alternatives is sufficient to provide for a general understanding of possible impacts, including a full reduction of domestic and irrigation water in some areas. The foreseeable consequences of full reductions in water supply are described in **TA 16,** Socioeconomics and **TA 17,** Population and Land Use; and Shortage Allocation Model and Alternative Distribution Model results are shown in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, for shortages of 5 maf per year.

R.3.7.4. Preferences on Allowable Uses in the Lower Basin

Summary

Commenters expressed a variety of preferences for how water should be used. Golf courses, surf parks, and decorative lagoons were suggested to be eliminated from Lower Basin uses before shortage is considered as a policy tool. Other commenters urged protection of legal rights to use water, including for purposes that support community amenities.

Response

In general, the 1922 Colorado River Compact contemplated domestic and agricultural uses of Colorado River water, as defined in Article II(h). Relevant state or local laws may regulate or limit water use, or types of economic developments, within their jurisdictions. Any analysis of potential limitations on beneficial water use, including review under 43 Code of Federal Regulations (CFR) Part 417, are outside the scope of this EIS.

R.3.7.5. Quantification and Modeling of Lower Basin Water Demands

Summary

Some commenters expressed concern that modeled Lower Basin water demands, in the Shortage Allocation Models and CRSS modeling, were, for some users, unrealistically high and reached full use of entitlements sooner than should be expected. Other commenters expressed concern that their individual modeled consumptive use under-represented their planned increase of water use, and that the modeling resulted in limited availability of water to junior users and had the result of skewing risk to those users. Additionally, comments expressed that evaporation, system losses, and Lower Basin tributary use should be included in Lower Basin use to fully represent the balance of supply and demand.

Response

Modeling assumptions with respect to the projections of future water demand in the Lower Basin were necessary in order to analyze potential impacts on hydrologic and other environmental resources and are not intended to interpret specific provisions of the Law of the River or the state laws of any of the Basin States.

The Shortage Allocation Modeling was based on assumed full use (demand) of all entitlements. The Lower Basin demands used in CRSS were assumed to start near recent levels, including recent consumptive use efficiency, and then grow to full entitlement by 2040 for all users except the junior-most entitlement holder in each state. This approach resulted in an analysis that disclosed the maximum impacts to the junior users for priority based shortages; disclosed the maximum impacts to higher priority users for pro rata based shortages; analyzed a period where not all users were at full entitlement; analyzed a period where all higher priority users were at full entitlement; and provided a range of impacts on the other flow-based resources at and downstream of Hoover Dam due to the growing demands used in CRSS. This approach broadly encompasses any effects from actual uses and shortage sharing. Moreover, this approach is appropriate for the analysis as it provides maximum impacts to shortage levels and water users due to dry hydrology.

Lower Basin evaporation, system losses, and Lower Basin tributary use are all included to varying degrees in CRSS, meaning that all analyses show how the specified Lake Powell operations and Lower Basin shortage volumes affect the system conditions after Lower Basin evaporation, system losses, and historical levels of Lower Basin tributary use occur. CRSS explicitly models evaporation at Lake Mead, Lake Mohave, and Lake Havasu; **Appendix A,** CRSS Model Documentation has been updated to document this. System losses in the Lower Basin include flows to Mexico in excess of the 1944 Water Treaty, water bypassed pursuant to International Boundary Water Commission (IBWC) Minute 242, transmission losses, phreatophyte use, and other evaporative losses. Both flows to Mexico in excess of the 1944 Water Treaty and water bypassed pursuant to IBWC Minute 242 are explicitly modeled in CRSS using historical average values; **Appendix A** has been updated to document these values. Transmission losses, phreatophyte use, and other evaporative losses are included in the development of Lower Basin inflows used in CRSS. Any losses that occur downstream of Hoover Dam are implicitly included by lowering the computed intervening flow in these reaches. Then, CRSS uses these inflows, which reflect a historical range of these losses.

CRSS currently relies on historical gage inflow for the Lower Basin tributaries, including the Little Colorado, Virgin, and Bill Williams Rivers. The gage flow for these tributaries reflects all upstream uses, thus CRSS incorporates the historical range of use that has occurred in these tributaries. In the 2012 Colorado River Basin Water Supply and Demand Study, Reclamation committed to developing natural flows for the Little Colorado, Virgin, and Bill Williams Rivers. In January 2026, Reclamation published the updated and consistent 1971-2024 CU&L data for these tributaries. Reclamation is currently working to incorporate these data into the Natural Flow and Salt model to develop Lower Basin natural flow for these years; however, before these natural flows can be used in CRSS, future demand projections in these same tributaries need to be developed with Arizona, Nevada, Utah, and New Mexico, and Reclamation will need to consider extending the CU&L estimates back through 1906. While CRSS considers tributary use for modeling purposes, Lower Basin tributary uses are outside the scope of this EIS and separate from mainstream operations.

R.3.8 Lower Basin Conservation and Storage and Delivery of Conserved System and Non-System Water

Theme Summary

Comments on Lower Basin conservation and storage and delivery of conserved system and non-system water addressed two key areas. First, the comments discussed the storage and delivery of conserved water by users, currently referred to as ICS, and the extension or replacement of ICS. Second, they included comments on system conservation, the creation of which has historically been federally funded, to benefit Lake Mead elevations, and not recoverable by users. Comments were generally supportive of both system conservation and ICS, with specific concerns that varied by commentor, and with some comments noting the performance benefits and importance of incorporating flexible, adaptive tools for conserving, storing, and managing water. The comments received on system conservation expressed support for continued funding of system conservation, with some expressing the importance of it being verifiable.

Comments on ICS generally supported at least maintaining the existing ICS rules, with several comments expressing the need to expand participation in ICS, modify the rules for when and how ICS is used, and improve the consistency of what conservation is eligible for ICS. Multiple comments expressed the need for ICS to be operationally neutral with respect to reservoir operations. There were conflicting comments regarding whether ICS should be allowed to offset/meet required Lower Basin shortages. Some commenters noted that ICS storage must remain fully isolated downstream of Lee Ferry while others highlighted the benefits of being able to move stored water between Lake Powell and Lake Mead to manage water supply risks, benefit resources, and protect critical infrastructure. Some commenters are concerned that ICS deliveries effectively provide junior priority entitlement holders with a senior priority. Some comments stated that Reclamation failed to identify the agreements or authorities that are needed for protection pools in the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Finally, some comments expressed that any future ICS program should include transparent accounting and verifiable tracking.

Theme Response

Voluntary conservation through ICS and system conservation agreements has been a critical tool in the Lower Basin, helping reduce system risk and avoid involuntary reductions. Since 2012, approximately 10.4 maf of additional voluntary conservation has been created by the Lower Basin and Mexico, equivalent to approximately 150 feet in Lake Mead elevation. While future system conservation agreements funded by the federal government are subject to the future availability of federal funding, it is reasonable to expect that ICS-like tools will continue to be used in the Lower Basin to manage and may reduce the likelihood of large-scale mandatory reductions. All conservation is verifiable, and Reclamation has documented users' and states' total water use and conservation in the Lower Colorado Mainstream Accounting and Water Use Report each year.

All alternatives modeled in the Draft EIS respected the delivery rules associated with ICS that exists in Lake Mead at the end of 2026, while all action alternatives (except for the Basic Coordination alternative) included a new storage and delivery mechanism with varying rules and additional flexibilities. Across these alternatives, the rules for the new mechanism evaluated both operationally

neutral and non-operationally neutral storage mechanisms, varied the maximum accumulation and annual storage and delivery constraints, and varied the conditions when delivery of ICS was not allowed (e.g., when Lake Mead is below a specified elevation). Additionally, the Maximum Operational Flexibility Alternative evaluated the ability to store water in Lake Mead or Lake Powell, while the other action alternatives limited the storage to Lake Mead. The Draft EIS evaluated a range of options so that the eventual preferred alternative would fall within the range of already evaluated options and conditions. The specific rules for any new storage and delivery mechanism would be based on consensus agreements.

Modeled water deliveries, which may include delivery of existing ICS or new stored water in a particular scenario, followed the storage and delivery rules outlined in each alternative in conjunction with how a water user's entitlement was modeled in the alternative. Modeled delivery of existing ICS or delivery of new stored water are independent of a water user's priority and only follow the rules explored in the alternative. **Section R.3.1**, Secretarial Authorities discusses the approach taken in the Draft EIS with respect to specific authorities for different options, including the protection pools in the Enhanced Coordination and Maximum Operational Flexibility Alternatives. ICS creation and delivery are documented in the Lower Colorado Mainstream Accounting and Water Use Report each year and would continue to be with any ICS-like program in the future.

R.3.9 Tribal Considerations

Theme Summary

Across the comment letters submitted by Basin Tribes, several overarching considerations emerged, including the protection of tribal rights and trust assets, interpretation of legal authorities, concerns with the adequacy of the technical impact analysis, and the lack of meaningful tribal consultation and involvement in the Post 2026 process. Comments from tribes that relate to particular issues are captured in specific themes and are addressed in the corresponding sections where those themes are discussed.

Tribes expressed that the Draft EIS does not adequately acknowledge, analyze, or protect tribal water rights, Indian trust assets, or the legal authorities that govern Colorado River operations. Concerns include the lack of clear recognition of existing tribal rights; the potential for unlawful or inequitable shortages to tribes; improper treatment of system losses; and inadequate analysis of cultural, environmental, and socioeconomic impacts. Tribes also emphasized the need for a dedicated Federally Managed Water Resources Pool or similar mechanism in Post 2026 operations to ensure tribal rights are protected and not diminished during shortages. Tribes stated that the Draft EIS exceeds Reclamation's operational authority and fails to analyze required Upper Basin delivery obligations. Tribes raised concerns that the Draft EIS lacks required NEPA analysis, including impacts of shortages, dead pool conditions, Central Arizona Project (CAP) water quality, system infrastructure constraints, socioeconomic impacts, and mitigation measures. Tribes also noted that viable alternatives were not considered or analyzed, such as the alternative that the Gila River Indian Community submitted. Comments also highlight that some modeling assumptions are inappropriate or incomplete, including assumptions about Upper Basin actions, hydrology, and Lower Basin priority structures. In addition, some tribes have expressed a general concern that their water rights are not always fully usable on their own lands, which can negatively affect their

communities and governance. For example, Colorado River Indian Tribes (CRIT) has commented that, as a result, despite being authorized under *Arizona v. California* and the Law of the River, CRIT experiences harm to its members, its culture, and its sovereignty when water allocated to CRIT is unable to be consumptively used on reservation lands and is diverted from the Colorado River for consumptive use elsewhere in the basin without CRIT's approval.

Tribes requested government-to-government consultation, both during the development of the Draft EIS and in future decision processes. They emphasized the need for consultation that encompasses cultural practices, traditional cultural places, sacred sites, treaty and Winters rights, and Indian trust assets, as well as for transparency about how tribal input influences alternative development. Tribes also stated that Reclamation failed to consult under the National Historic Preservation Act (NHPA) and that overall engagement to date has been insufficient. More broadly, tribes seek meaningful, formalized consultation processes aligned with existing mechanisms and a role in the Post 2026 process comparable to the Basin States.

Theme Response

Reclamation identified tribal water entitlements in the Basin (by tribe, and also grouped by priority, location, or other characteristics if applicable), Indian trust assets, and the legal authorities that govern Colorado River operations. Nothing in the EIS is intended to modify tribal water entitlements or preclude future tribal water rights settlements or adjudications. Reclamation acknowledged that the agency cannot unilaterally implement certain operational elements included and analyzed in the Draft EIS, as many of these actions would require implementation agreements among various Basin entities (see **Section 2.3**). Should Basin States and tribes develop agreements that avoid or mitigate any needed reductions or otherwise share shortages, the broad range of alternatives analyzed in the Draft EIS provides environmental compliance for alternative approaches to distributing water deliveries and any shortages, including approaches that differ from a priority-based shortage distribution in the Lower Basin. Many viable elements submitted through alternative proposals were incorporated into the broad range of alternatives evaluated in the Draft EIS. Reclamation also believes the Draft EIS adequately analyzes, to the extent required, the potential impacts of operations and shortage distribution on tribes and is consistent with the Department's trust responsibilities.

Throughout the Post-2026 NEPA process, Reclamation has consulted both formally and informally with Basin Tribes. This includes several invitations at critical milestones for government-to-government consultation, as well as regular communication and updates provided through the monthly Reclamation-hosted Tribal Information Exchanges and other tribal forums to which Reclamation leadership and staff are invited, such as Ten Tribes Partnership meetings and Inter Tribal Council of Arizona meetings. In addition, during the alternatives development phase, a tribal workgroup was convened and met regularly with tribal staff and representatives to identify and discuss tribal priorities and ensure these were reflected within the Draft EIS range of alternatives. The ROD will include language describing future tribal consultation requirements for implementation decisions related to post-2026 operations. Regarding NHPA consultation, this issue is outside the scope of the EIS process and is addressed through the NHPA process.

R.3.10 Hydrologic Modeling Assumptions

Theme Summary

Commenters argued that the technical analysis was inappropriate due to several modeling assumptions. Some described the initial reservoir conditions as optimistic and outdated. Others characterized the future hydrology assumptions as unrealistic, lacking predictability, and inconsistent with the best available science, including climate change. Commenters also described Upper Basin demand projections as showing unrealistic growth. With respect to Lower Basin demands and system losses, commenters stated that these were not fully represented, citing specific concerns including the exclusion of tributary uses and assumptions related to 2040 build-out. Additional comments noted that "gap water" is not clearly identified or consistently described throughout the Draft EIS, and that evaporation assessments on reservoir pools should be more clearly described.

Response

With respect to initial conditions, the choice in November 2024 to use a wide range of 2027 initial reservoir elevations for the Draft EIS analysis was appropriate given that modeling had to begin approximately 2 years before the start of the new guidelines, and there was significant uncertainty about hydrology in 2025 and 2026. The initial conditions were taken from the best available mid-term projections at that time. Because the Low initial conditions used in the Draft EIS are reasonably representative of where the system will be starting in 2027, the Final EIS shows impacts based only on the Low initial conditions. See **Appendix G,** CRSS Initial Conditions, for a comparison of current projections and the Low initial conditions.

With respect to hydrology, the choice to use Decision Making under Deep Uncertainty (DMDU) as the analysis framework necessitates incorporating a wide range of conditions, and the set of hydrologic model inputs is appropriate for this purpose. The DMDU framework evaluates how each alternative performs across a wide range of plausible future hydrologic and operational conditions. Rather than relying on a single predicted future, this approach provides insight into how an alternative performs across a broad range of future conditions. These methods and choices are well documented in **Appendix E,** DMDU Overview and Approach and **Appendix F,** Approach to Hydrologic Uncertainty.

In response to comments regarding climate change, Reclamation has been involved in scientific studies related to climate projections over the past several decades. Those efforts are reflected in some of the hydrologic inputs used in this analysis, and the DMDU framework evaluates the alternatives across a wide range of hydrologic uncertainty, including uncertainty associated with climate trends.

For discussion about Upper Basin demands, see **Section R.3.4**.

With respect to Lower Basin demands and system losses, including tributary use, Reclamation recently completed an effort to recalculate and release Lower Basin CU&L data through 2024, published in December 2025. Reclamation is also developing updated natural flow estimates, though these data were available in time for incorporation into this analysis. Additional analysis of Lower Basin evaporation and system losses, however, are outside the scope of this EIS. Methodologies for

developing these datasets are presented in "Estimates of Evapotranspiration and Evaporation Along the Lower Colorado River," published by Reclamation in early 2024; that report does not, however, make recommendations for implementing or accounting for system losses from the Lower Colorado River mainstem. For a discussion of modeling assumptions related to Lower Basin demand, including build-out assumptions, see **Section R.3.7.5**, Quantification and Modeling of Lower Basin Water Demands.

With respect to comments regarding "gap water," **Chapter 2** and **Appendix S**, Additional Description of Alternatives, provide a clear description of gap water, and detailed CRSS modeling assumptions are provided in **Appendix A**, CRSS Model Documentation. Additionally, **Appendix D**, Sensitivity Analysis - Effects of Natural Flow Percentage Used for the Supply Driven Alternative, provides a quantification of gap water.

In response to comments regarding the clarity of the evaporation assessment for the storage and delivery of conserved system and non-system water mechanism, the evaporation assumptions vary by alternative: some alternatives apply an annual percentage, while others are based on the actual evaporation of the reservoir in which the water is stored. These assumptions are described in detail in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

R.3.11 Alternatives Development/Range of Alternatives

R.3.11.1. Range of Alternatives

Summary

Commenters state that the Draft EIS does not include a reasonable range of technically and economically feasible alternatives. Certain commenters note deficiencies in the treatment of Compact compliance, citing an over-reliance on Lower Basin reductions and a lack of clearly defined Upper Basin conservation and operational commitments. Commenters state that alternatives should disclose connected actions and operational details sufficient for meaningful public and decision-maker review.

Additional commenters assert that the range of alternatives is inadequate because certain submitted proposals or concepts (such as those advanced by the Upper Division States, Lower Division States, Gila River Indian Community, and Colorado River Indian Tribes) were not fully analyzed as standalone alternatives. Other commenters expressed the opposite view, that the Draft EIS considers too many concepts or includes operational elements they believe are outside the appropriate scope of this NEPA review, are infeasible, rely on speculative assumptions about actions outside Reclamation's control, are not in compliance with the Law of the River, or are otherwise beyond existing authority.

Response

Reclamation developed and screened alternatives in accordance with NEPA, which requires agencies to evaluate a reasonable range of alternatives that meet the Purpose and Need for the Proposed Federal Action. This Final EIS evaluates the environmental effects of six alternatives, including the

No Action Alternative, as required by NEPA, and five action alternatives. As described in **Chapter 2** and **Appendix S**, Additional Description of Alternatives, alternatives and operational elements were developed through multi-year engagement and then screened based on alignment with the Purpose and Need, technical and economic feasibility, a reasonable expectation that necessary authorities could be pursued, and the ability to meaningfully analyze environmental effects of the alternatives within the Final EIS.

In response to comments requesting a broader range of alternatives, Reclamation notes that numerous concepts, including proposals submitted by stakeholders and the Basin States, were considered during the alternatives development process. As described in **Chapter 2** and **Appendix S**, these concepts and proposals informed the development and screening of the alternatives carried forward for detailed analysis. An EIS is not required to analyze every alternative proposed during scoping or public review, but rather to rigorously explore and evaluate a reasonable range of alternatives that are feasible and that meet the Purpose and Need for the proposed action. The fact that a particular proposal was not advanced as a standalone alternative does not mean it was disregarded. Many elements of submitted proposals were incorporated into the development, refinement, or comparative analysis of the alternatives evaluated in the Final EIS.

With respect to the Upper Division States' and Lower Division States' proposals, Reclamation considered those proposals during alternatives development, considered the respective revisions submitted in winter 2024, and evaluated whether they provided an appropriate basis for comprehensive and coordinated operations of Lake Powell and Lake Mead consistent with the Purpose and Need. Reclamation worked extensively with both the Upper Division States and Lower Division States to not only understand and gather information, but also to model and perform detailed analysis of their respective proposals. As described in the Final EIS (see **Section 2.1**), the Basin State proposals, as submitted, were not included as standalone alternatives because they did not include appropriate bases for the comprehensive and coordinated operations of Lake Powell and Lake Mead.

Reclamation incorporated elements of the submitted proposals, along with concepts generated during Reclamation's engagement with the Basin States throughout 2025, to inform the development and refinement of the action alternatives that were carried forward for analysis. After continued work with all seven states throughout the spring and summer of 2025, the concept that became the Supply Driven Alternative was actively being considered by all states but had not achieved full agreement. Because there was no consensus-based alternative, the Draft EIS attempted to capture the state of discussions through inclusion of the Supply Driven Alternative but did not identify a preferred alternative. After publication of the Draft EIS, coordination with the States continued although the discussion had moved away from the concept of the Supply Driven Alternative.

In addition to the individual state comments submitted on the Draft EIS that contained proposed operational strategies, the Upper Division States and Lower Division States submitted additional proposals in May 2026 after the publication of the Draft EIS. The proposal submitted by the Lower Division States described a 2-year set of operating guidelines through 2028 as a bridge to allow future opportunity to reach a consensus-based long-term solution. The Preferred Alternative

identified in the Final EIS incorporates concepts from the States' proposals and leaves open the opportunity for Basin entities to subsequently arrive at a consensus-based path forward. Should no consensus emerge, the Preferred Alternative ensures that the Secretary will have the flexibility to make necessary operational decisions.

R.3.11.2. No Action Alternative

Summary

Commenters disagreed with the characterization of the No Action Alternative, stating that it did not represent a baseline for comparison and a return to implementation of the LROC under a pre-2007 Interim Guidelines framework. For example, commenters stated that the No Action improperly limits the Secretary's authorities to take actions to protect infrastructure and incorrectly limits Lower Basin shortages to 600 thousand acre-feet, the maximum Lower Basin shortage from the 2007 Interim Guidelines. Commenters expressed concern that limiting shortage to that amount would fail to protect infrastructure at Glen Canyon Dam. Commenters also stated that the No Action Alternative represented a misapplication of the LROC because itimproperly sets the annual release to a fixed volume of 8.23 maf. Finally, commenters state that the No Action Alternative fails to meet the Purpose and Need.

Response

As described in the Final EIS (**Appendix S**, Additional Description of Alternatives), Reclamation based the No Action Alternative on the operating guidance that was in place before the adoption of the 2007 Interim Guidelines ROD to provide a reasonable representation of how the system would continue to operate if no additional operating guidelines were adopted. Before the 2007 Interim Guidelines were in place, the basis for operations was the narrative provisions of the LROC, under which the Secretary made a number of determinations at the beginning of each operating year as described in the Annual Operating Plan for Colorado River Reservoirs, including the water supply available to users in the Lower Basin and the annual release from Lake Powell. The LROC does not include specific guidelines for such determinations, so the outcome of the annual determination in any particular year in the future could not be precisely known. However, a reasonable representation of future conditions under the No Action Alternative is needed for comparison to each action alternative. The modeling assumptions used for this representation are consistent with assumptions used in previous environmental compliance documents, most recently the 2007 Interim Guidelines, with appropriate refinements. The assumptions used in the No Action Alternative are not intended to limit or predetermine any future decision by the Department.

As the Final EIS explains in **Appendix S** and **Section 3.2.3**, the No Action Alternative appropriately describes an operational framework that reverts to implementing LROC similar to what occurred before the 2007 Interim Guidelines. The expiration of current domestic and international implementing agreements means that the No Action Alternative represents a change in operations. As a result, the No Action Alternative does not serve as an appropriate baseline to compare impacts. Therefore, a Continued Current Strategies Comparative Baseline scenario is provided to assess the impacts if operations were to continue under the current direction and strategies. While the Continued Current Strategies Comparative Baseline is not an action alternative,

it is a contemporary set of operations that stakeholders are familiar with that can be used to comparatively evaluate the performance of the alternatives (including the No Action Alternative).

Regarding Lower Basin shortages, as described in **Appendix S** of the Final EIS, in accordance with the Consolidated Decree and the LROC, the Secretary makes a determination each year as to whether the consumptive use requirements of mainstream users in the Lower Division States will be met under a Normal, Surplus, or Shortage Condition. The LROC specify that the Secretary will consider all relevant factors in making a shortage determination and list some of the factors to be considered. However, there is no specific LROC guidance as to exactly when, how, or to whom reductions in deliveries would be made under the No Action Alternative in the absence of set operating guidelines. Therefore, it is impossible to know exactly how the Secretary might make a shortage determination from year to year in the future. To provide a representation of how decisions may be made under the No Action Alternative for the purposes of analysis, the elevations and volumes adopted in that ROD are assumed for this alternative. The Final EIS considers a range of Lower Basin Shortage maximums to illustrate impacts and tradeoffs associated with each. Regardless of the alternative considered, the Secretary has the vested authority and responsibility to operate the System through coordinated operations, including the ability to respond to exigent and emergency conditions, pursuant to applicable federal law, the Decree, contractual obligations, and other elements of the Law of the River.

The narrative provisions of LROC are used to make determinations with respect to storage reservoirs in the Basin under the No Action Alternative. Annual releases from Lake Powell that vary from 8.23 maf are analyzed in other action alternatives in the Final EIS. For more information on LROC Implementation, see **Section R.3.5**.

The No Action Alternative is not required to meet the Purpose and Need for the proposed action. It is included as a baseline for comparison against the effects of the action alternatives.

R.3.11.3. Preferred Alternative

Summary

Commenters asserted that the absence of a preferred alternative in the draft EIS limited meaningful opportunity for public comment.

Response

The Draft EIS is designed to present and evaluate a reasonable range of alternatives with sufficient detail to support informed decision-making and allow for meaningful comparison of effects consistent with Purpose and Need. NEPA does not require identification of a preferred alternative in a Draft EIS, and an agency may choose to identify, develop, or refine a preferred alternative in the Final EIS. The Representative Preferred Alternative for this Proposed Federal Action was developed following the release of the Draft EIS, and is further described in **Chapter 2**, Description of Alternatives.

Several commenters requested additional detail regarding authorities, Compact compliance assumptions, and the treatment of actions outside Reclamation's control. Reclamation's evaluation

of alternatives is conducted within the context of the Law of the River and applicable authorities, and the EIS does not resolve disputed legal interpretations. For comment topics focused on authority or legal interpretation, see the Theme Summary/Response for **Section R.3.1**, Secretarial Authorities and **Section R.3.18**, Policy and Governance. For comment topics focused on Compact compliance concepts or differing Compact interpretations, see **Section R.3.2**, 1922 Colorado River Compact Compliance.

For comment topics requesting additional disclosure of connected actions, third-party actions, or operational details outside the scope of this EIS, see **Section R.3.21**, Connected Actions and Cumulative Effects and **Section R.3.19**, Scope. For comment topics requesting detailed analysis of specific concepts that were screened out, see **Section R.3.13**, Alternatives Considered but Eliminated. For comment topics seeking additional specificity regarding Upper Basin conservation assumptions and feasibility, see **Section R.3.4**, Upper Basin Demands, Shortage, and Conservation. No Action sub-theme: Cross-reference to LROC and infrastructure protection sections. Under NEPA, an agency is required to describe a "no action" alternative in an EIS. Consistent with the No Action Alternative analyzed in the 2007 Interim Guidelines Final EIS, the No Action Alternative is based upon operating guidance that was in place before the adoption of the 2007 Interim Guidelines ROD to provide a reasonable representation of how the system would continue to operate within existing authorities if no additional operating guidelines were adopted and absent additional agreements. It represents a return to operations preceding development of the 2007 Interim Guidelines and is necessary as a comparison for each action alternative. The No Action Alternative is not required to meet Purpose and Need.

R.3.12 Coordinated Operations of Lake Powell and Lake Mead

Theme Summary

Many commenters expressed views on how to prioritize resources and which criteria to use when determining coordinated operations, particularly for operations at Lake Powell. Commenters identified specific Lake Powell elevations that should be maintained, such as 3,570 feet for the purposes of protecting native fish in the Grand Canyon, and 3,525 feet to preserve the ability to perform high-low experiments (HFEs). Others suggested that prioritizing reservoir storage for water security or recreation purposes was important, or that ensuring reservoirs could continue to generate hydropower was critical. Some highlighted the importance of basing operations on observed inflows to Lake Powell, and to allow releases to reflect hydrologic variability in a more natural way.

Response

Reclamation recognizes that the Colorado River supports many important and valuable resources, and that stakeholders throughout the Basin prioritize these resources differently. During the alternatives development process, Reclamation ensured that the action alternatives in the Draft EIS reflected a wide range of Lake Powell operations that achieved different balances of performance across resources. The Enhanced Coordination and Maximum Operational Flexibility Alternatives were designed specifically to account for different resource values. Additionally, the Draft EIS alternatives capture a wide range of operating criteria, including the explicit use of hydrology in determining releases. Finally, the Draft EIS analysis describes how these resources perform and by looking at a wide range of resources, the tradeoffs across priorities are reflected.

R.3.13 Alternatives Considered but Eliminated

Theme Summary

Some commenters requested a detailed analysis of alternatives that were identified in the Draft EIS as considered but eliminated, including structural modifications to Glen Canyon Dam, such as a river-level bypass and improvements to outlet works. Requests were made to analyze one-dam alternatives that would prioritize the preservation and operation of a single mainstream reservoir—either Hoover Dam/Lake Mead or Glen Canyon Dam/Lake Powell—over the other. The majority of these commenters supported a 'Fill Mead First' alternative, including proposals to bypass or decommission Glen Canyon Dam. Other requests questioned the exclusion of ecosystem-first alternatives, and recreation-focused plans from analysis. Some comments expressed general agreement or disagreement with the elimination of an alternative from detailed analysis.

In some cases, commenters took issue with specific aspects of the rationale for not analyzing the alternative in detail. For example, some commenters questioned how the Ecosystem Alternative would not fully resolve the operational and legal requirements for managing Colorado River water and noted that, while an ecosystem-based alternative would include cuts to water allocations and implementation of water conservation measures, alternatives considered in detail also involve these elements. Other commenters stated that there were more flexibilities within the concept of a "Fill Mead First" Alternative that could allow it to be implemented in a manner consistent with the Law of the River.

Theme Response

Consistent with NEPA requirements and as described in **Chapter 2** and **Appendix S**, Additional Description of Alternatives, this Final EIS focuses detailed analysis on a reasonable range of alternatives. A reasonable range of alternatives under NEPA provides decision makers and the public with a meaningful basis to compare environmental impacts and make informed choices. NEPA does not require that the scope of alternatives included be exhaustive, and agencies do not need to consider alternatives that are infeasible, ineffective, or otherwise inconsistent with the objectives of the proposed federal action. Alternatives, operational concepts, or components of alternatives that were considered but not carried forward for detailed analysis are documented in **Appendix S** of the Final EIS, with explanations for the bases for their elimination. This response further clarifies the rationale for eliminating specific alternatives –Fill Mead First approach, ecosystem-first alternatives, and recreation-focused plans— from detailed analysis.

An ecosystem-first alternative generally refers to a management framework that prioritizes the long-term ecological function of the Colorado River system over congressionally authorized project purposes. An ecosystem-first operational framework would limit operational flexibility or require extensive changes to Colorado River operations and contracts and would reduce water supply for users based on prioritizing ecological thresholds and constraints. Thus, while specific ecosystem considerations and objectives were incorporated into the EIS, the EIS does not analyze a stand-alone ecosystem-first alternative.

A 'Fill Mead First' alternative proposes an operational strategy that prioritizes Lake Mead as the primary water storage facility on the mainstream Colorado River and subordinates Lake Powell as a

secondary water storage facility operationally dependent upon storage conditions at Lake Mead. This alternative was not included in the Final EIS because it would not meet the Purpose and Need of the proposed federal action, lacks fundamental compliance with the Law of the River, and would require extensive changes to Colorado River operations and contracts. A Fill Mead First approach likely would need to involve a novel inter-basin water storage exchange or conservation pool. It would alter the purpose of the guidelines for coordinated operations of both Lake Powell and Lake Mead, under the existing statutory and legal structure, without Congressional authorization. The purpose and need of this EIS supports the development of operational guidelines for the management of the existing reservoirs, which includes a fundamental assumption of the continued existence of and congressionally authorized purposes of Lake Powell and Lake Mead. This EIS analyzes alternatives within operational objectives designed to protect critical infrastructure, maintain water delivery reliability, preserve operational capability, and maintain system flexibility. A one-reservoir alternative, such as the Fill Mead First approach, would require significant legal, engineering, financial, and congressional action. The Fill Mead First alternative and other alternatives regarding decommissioning Glen Canyon Dam were rejected in the 1995 EIS on Glen Canyon Dam operations and in LTEMP for similar reasons.

Regarding modifications to Glen Canyon Dam infrastructure, specific infrastructure modifications are not currently contemplated as components of individual alternatives within the EIS, since pursuing them would be outside the scope of adopting specific operational guidelines, and operational guidelines must be adopted as a result of this process whether or not any infrastructure modifications are pursued in a separate action. See theme response **Section R.3.6**, Glen Canyon Dam and Hoover Dam Infrastructure, for additional information.

R.3.14 Sustainable, Reliable, and Adaptive Management

Theme Summary

Commenters advocate a proactive, science-based management framework that internalizes long-term aridification, employs realistic supply projections, and prioritizes demand reduction and conservation over perpetuating unsustainable allocations. Commenters call for transparent modeling and reporting and integrated ecological stewardship. Many commenters asked for the inclusion of riparian restoration, invasive species control, and sediment and temperature management. Requests were made for flexible tools that scale to actual hydrologic conditions and are developed within operational decision-making, rather than deferred to reactive compliance documents. Suggested instruments include enforceable efficiency standards, incentives and mandates for agricultural modernization and crop substitution, expanded off-stream storage and recharge, transparent accounting of avoided spills, and clearly specified ecological thresholds (e.g., Powell elevation targets for temperature control; minimum Grand Canyon flows; monthly release limits and HFE frequency contingent on sediment).

Response

Reclamation considered sustainable, reliable, and adaptive management while developing the Draft EIS and Final EIS. Many of the concepts that commenters requested have been incorporated into the Final EIS, including proactive and science-based management. However, some concepts raised by commenters were outside the scope of this EIS or were in the realm of state and local

jurisdictional decisions, including implementation of incentives and mandates for specific agricultural practices and development of expanded off-stream storage projects. Other requests will be addressed, where appropriate, through subsequent NEPA and Endangered Species Act (ESA) efforts or through programmatic and operational planning efforts beyond this EIS.

R.3.15 Mitigation

Theme Summary

Commenters asserted that the Draft EIS mitigation discussion is inadequate under NEPA/Council on Environmental Quality standards and seek integrated, enforceable, and funded mitigation tied to each alternative, with monitoring, adaptive triggers, and long-term management. Proposed measures include direct assistance and replacement supplies to tribes where deliveries are reduced; transactional flexibility and accounting for conserved water; compensation frameworks linked to modeled damages and improved conveyance infrastructure. Biological mitigation requests emphasize thresholds for critical habitat, native fish passage protection, non-native control, HFE regimes to rebuild habitat, and expanded conservation areas. Commenters suggested proactive coordination with stakeholders, including the National Park Service, to evaluate and implement adaptive management and infrastructure solutions to mitigate potential adverse effects on water-dependent recreational activities. Socioeconomic mitigation measures include workforce transition programs, compensated conservation that maintains agricultural viability, and targeted responses for the Salton Sea (dust suppression, habitat restoration, human health responses, and infrastructure investments).

Response

The Draft EIS complies with current Department regulations and guidance for NEPA compliance, including the DOI NEPA Handbook (516 DM 1, February 2026). The Handbook explains that although "NEPA requires bureaus to consider reasonable mitigation measures, it does not require bureaus to evaluate or select any specific form of mitigation." NEPA does not independently confer authority on agencies to require, fund, or enforce mitigation measures absent separate substantive authority.

The proposed federal action and alternatives include review of the environmental effects of mitigation measures, and such mitigation approaches are described at a programmatic level and are commensurate with the planning-level nature of this EIS. Compliance under other laws, including the ESA, may provide additional specific mitigation measures. Reclamation would continue to coordinate with the appropriate stakeholders during the implementation of a selected alternative. Historically, this coordination provides for additional tools to minimize impacts.

R.3.16 Decision Process

R.3.16.1. Preferred Alternative Selection

Summary

Commenters requested transparent decision criteria for selecting a Preferred Alternative, including explicit articulation of the Secretary's vision and clearer grounding in current hydrologic realities.

Several commenters argued that a Preferred Alternative should have been identified for public review in a revised or supplemental draft prior to issuance of the Final EIS.

Response

NEPA does not require a preferred alternative to be identified in the Draft EIS. The alternatives analyzed in this Final EIS include a broad range of operational elements incorporating over 4 years of input provided by stakeholders and the public and received through consultations with the Basin States and Basin Tribes, the alternatives development process is described further in **Chapter 2**. In the absence of a long-term consensus-based approach, Reclamation has developed a Preferred Alternative that consists of a decision framework to develop operating guidelines for Lake Powell and Lake Mead for operating years 2027 through 2036. This framework provides near-term certainty and predictability for Lake Powell and Lake Mead operations, establishes a transparent process for making operational decisions in the absence of long-term consensus, and allows for incorporation of future consensus recommendations while preserving the flexibility to respond to changing hydrologic conditions. The process and timeframes are explicitly designed to facilitate consideration of and response to hydrologic conditions. Should no consensus emerge, the Preferred Alternative ensures that the Secretary will have the flexibility to make necessary operational decisions.

R.3.16.2. Implementation of Annual Decision-making

Summary

Commenters requested improved stakeholder inclusion in annual operational decision-making. Specific suggestions for this include forming a basin-wide adaptive management advisory body with transparent data and annual criteria and sustaining ongoing consultation throughout implementation and adjustments over time.

Response

The Department is tasked with determining annual operations in consultation with the States. Additional consultations and processes, including engagement with tribes, are important for achieving a decision. However, it is not necessary to fully describe and analyze specific alternatives for annual operational decision-making as part of this NEPA process. The ROD will incorporate a consultation and outreach process to inform future post-2026 operational decisions.

R.3.17 Purpose and Need

Theme Summary

Commenters argue that the analyzed alternatives do not fully meet the stated Purpose and Need under dry and critically dry conditions and that performance thresholds are not coherently linked to stated objectives. For example, the Draft EIS identifies avoidance of Lake Powell dead pool-related reductions as a performance indicator for evaluating robustness, yet the analysis shows that none of the alternatives meet this criterion. Some commenters requested a broader, systemwide Purpose and Need that explicitly addresses structural deficit and Compact compliance, integrates ecological mandates and statutory responsibilities (Grand Canyon Protection Act of 1992 [GCPA], ESA, National Park Service Organic Act), and reflects persistent aridification rather than treating conditions as mere variability.

Theme Response

Under NEPA, a purpose and need statement is required to explain the basis for the federal action by identifying why the action is being considered and what the agency intends to accomplish. **Chapter 1** outlines the Purpose and Need for this Proposed Federal Action, as set forth in the *Federal Register* notice published on October 20, 2023 (88 *Federal Register* 72535). The purpose and need for this proposed federal action provides a framework for considering varied operational and management strategies within a reasonable range of alternatives by establishing management objectives, operational needs, and applicable legal or regulatory considerations. It is sufficiently broad to allow consideration of a reasonable range of alternatives, but not so broad that it becomes unbounded or speculative and defines a decision space that allows multiple implementable operational alternatives while remaining consistent with authority and physical system limits.

The scope of the federal action is the development of new guidelines and coordinated management strategies to address Lake Powell and Lake Mead through their full operating range to take effect when the current agreements expire in 2026. All the analyzed alternatives provide a wide range of operations that meet the purpose and need for the scope of this action, while highlighting the trade-offs between them in meeting the specific objectives of the purpose and need. As shown by the analysis, during dry and critically dry conditions, performance objectives may not be met, and the degree of impacts could be significant to users and resources. This is the inherent challenge with a finite resource in great demand. At this point, no other alternatives have been brought forward that would result in better performance and fewer impacts.

R.3.18 Policy and Governance

Theme Summary

Commenters emphasized adherence to the Law of the River and related authorities (or various interpretations thereof). Specific components mentioned by commenters included Articles III(c)–(d) of the 1922 Compact, the CRSP Act, CRBPA, the Consolidated Decree, LROC/602(a), and binational treaty obligations. Commenters requested Reclamation explain any perceived departures from their preferred interpretations, incorporate Compact compliance as an operational priority, and reconcile operations with obligations under GCPA and ESA. Additional comment themes include limitations regarding interstate and interbasin marketing, maintenance of hydropower production for authorized purposes while recognizing its subordination to agricultural and domestic uses, and attention to national policy linkages (e.g., critical minerals, energy, and security).

Response

The Secretary intends to consider, adopt, and implement the proposed federal action consistent with the Law of the River. The alternatives in this Final EIS are designed to cover a wide range of potential outcomes with respect to post-2026 operations; accordingly, they incorporate components that are within existing authorities along with components that would require new authorities and/or new agreements among Basin water users to fully implement, see **Section 2.3**. The EIS does not establish new legal interpretations, resolve contested questions about the 1922 Compact or other authorities, or modify existing governance frameworks. Rather, it evaluates the environmental consequences of potential federal actions across a range of alternatives, see further discussion in theme responses **Sections R.3.1** and **R.3.2**.

R.3.19 Scope

Theme Summary

Commenters indicated differing views on whether the analysis should be limited to Lake Powell and Lake Mead operations, or to expand the geographic scope, both upstream to include the CRSP Upper Initial Units and downstream to include Mexico. Other commenters asked for analysis of more localized impacts related to specific water users, water districts (e.g., Southern Nevada Water Authority, CAP contractors, and the Salton Sea). Comments also focused on the analysis scope, requesting additional analysis on their locally/privately owned non-Federal water delivery infrastructure, water leases, and quantification of effects on other water supplies, such as groundwater. Many point to analytical inconsistencies in which upstream releases or conservation are assumed but upstream impacts are not analyzed. Requests span analyzing Upper Basin shortages and conservation, incorporating transboundary effects under Executive Order 12114, and clarifying the geographic boundary relative to Lake Powell's full pool. Other comments cover a wide variety of topics that are not within the scope of this EIS, such as impacts on low-income and minority populations, impacts on water users who lease water from water right holders, impacts from sub-annual flows for ecological benefits, impacts related to infrastructure upgrades or modifications.

Response

Section 3.2 of the Draft EIS (Analysis Methods) includes a detailed discussion on how Reclamation defined the geographic, temporal, and analysis scope. The scope is expanded for certain resource analyses based on those particular resources, as described in the respective resource analysis sections. For many resources, expanding the scope of analysis introduces uncertainty into impact analysis because impacts and causal relationships will become more speculative, non-federal decision points are introduced, and Reclamation's authorities become more limited. These factors create a level of uncertainty that makes it impractical to analyze certain expanded resource areas. Reclamation clarified the text in **Section 3.2** of the Final EIS to better define the default geographic scope for analysis; specific resource topics (e.g., socioeconomic impacts) describe more expanded analysis scopes as applicable.

Proposed operations at the CRSP Upper Initial Units specifically contemplated in the alternatives informed the hydrological modeling in the Draft EIS. These operations are within the scope of each unit's existing RODs, and as such, the associated impacts are disclosed in the associated EISs. Specific conservation activities that may be undertaken in the Upper Basin are unknown at this time and would not necessarily require federal operational decision making. Any federal operational decisions associated with these conservation activities would undergo additional environmental compliance.

Deliveries to Mexico are determined by Treaty and international agreements. Modeling assumptions with respect to water deliveries to Mexico were necessary to analyze potential impacts on hydrologic and other environmental resources. Since Reclamation does not control the use and distribution of water in Mexico, direct impact analysis on specific resources would be speculative.

The Salton Sea is a terminal lake in Riverside and Imperial Counties, California. Lake levels are influenced by runoff from the surrounding Imperial Valley and Coachella Valley watersheds, as well

as agricultural drainage from the Imperial Irrigation District and Coachella Valley Water District. Reclamation does not manage or control the end use of water after the point of delivery. As such, Reclamation has no management authority over the distribution of end use or allocation by these water districts and individual users, including user decisions to participate in conservation programs. The State of California oversees management of the Salton Sea, and Reclamation has no management or enforcement authority over inputs to the Sea.

As a general matter, groundwater in Arizona is governed by state law, in particular the Arizona Groundwater Code, established by the Arizona Groundwater Management Act of 1980 as amended. See Arizona Revised Statutes (A.R.S.) Title 45, Chapter 2. The Arizona Groundwater Code is a "framework for the comprehensive management and regulation of the withdrawal, transportation, use, conservation and conveyance of rights to use the groundwater in this state." A.R.S. § 45-401(B). A state agency, the Arizona Department of Water Resources, has "general control and supervision" of groundwater in the state as provided by A.R.S. Title 45. See also 43 United States Code (U.S.C.) § 617q. Regulation of state groundwater thus is generally outside Reclamation's jurisdiction, with limited exceptions based in federal law. For example, exceptions may include federal actions under federal trust responsibilities and statutes related to Indian tribes, certain releases of hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. §§9601 et seq.), and in relation to the Colorado River, the subflow zone (e.g., A.R.S. § 45-596.01) and specific limitations related to CAP subcontracts as provided in the CRBPA, 43 U.S.C. 1524. Therefore, analysis related to any decisions made by Arizona water users to change or supplement water sources due to federal actions would be speculative. The purpose of this EIS is to analyze and disclose the reasonably foreseeable effects from the proposed action and alternatives within the defined area of analysis, and items outside this scope are therefore not included in the analysis. See **Section 1.5** of the Final EIS for additional details on the geographic scope affected by the proposed federal action. The Final EIS complies with current Executive Orders and Department regulations and guidance for NEPA compliance, including the DOI NEPA Handbook (516 DM 1, February 2026). The Handbook supplements the Council on Environmental Quality regulations (40 CFR 1500–1508) and Department regulations (43 CFR Part 46). The Draft EIS also complies with current Executive Orders related to NEPA analysis. For example, pursuant to Executive Order 14154, Unleashing American Energy (January 20, 2025), and the Presidential Memorandum entitled Ending Illegal Discrimination and Restoring Merit-Based Opportunity (January 21, 2025).

R.3.20 Data Sources

Theme Summary

Commenters requested that Reclamation use updated and transparent data sources, including the incorporation of updated capacity surveys, CU&L datasets (including Upper Basin and Lower Basin CU&L and evaporation), published materials related to drought science, and independent peer review. Commenters urged transparency around Lower Basin uses and losses and asked that model assumptions be refined to reflect current storage conditions, depletion schedules, and hydrologic conditions.

Response

Reclamation incorporated the best available science and all necessary data for the development of the Final EIS. Data sources, assumptions, and methodologies are documented in the EIS and supporting appendices to support transparency and reproducibility.

With respect to updated capacity surveys and Upper CU&L and evaporation data, the selection of data sources for the CRSS model had to occur 2 and 3 years, respectively, before EIS modeling began. At that time, these data sources represented the best available datasets. Lake Powell modeling relied on the 2017 Lake Powell Stage-Area-Capacity survey, which remains the most recent survey published and continues to represent the best available science. Upper Basin CU&L and evaporation were based on Upper Colorado River System CU&L data released in February 2022, covering the 1971-2020 period and including upper system reservoir evaporation.

These CU&L data are essential inputs for two critical datasets used in CRSS for the EIS modeling. The natural flow data and the UCRC depletion demand schedule. The 1906-2020 natural flow data was released in December 2022. The UCRC depletion schedule followed a more complicated development timeline.

The UCRC first released a supply-limited depletion schedule in June 2017, providing decadal depletion demand projection by state and major consumptive use sectors. Working with the UCRC and the Upper Division States, Reclamation translated these decadal projections into monthly, CRSS reach-scale inputs in November 2020. This supply-limited schedule pre-shorts demands in high Upper Basin tributaries that historically receive less than a full water supply, before inputting these schedules in CRSS.

In August 2021, the State of Colorado asked Reclamation to further refine and improve CRSS. One enhancement enabled the model to use a full-supply (rather than supply-limited) depletion demand schedule. In March 2023, Reclamation released CRSS version 6, which included the ability to short high-tributary water users dynamically during a model run. The UCRC then produced and published an updated 2016 depletion demand schedule compatible with CRSS version 6 in June 2022.

Reclamation released updated 1971-2023 Upper Basin CU&L data in June 2024. This update incorporated methodological changes to irrigated agriculture CU estimates, shifting CU among the Upper Division States. These shifts require development of a new UCRC depletion schedule when time allows. However, because EIS modeling commenced in November 2024, there was not sufficient time for the Upper Division States, the UCRC, and Reclamation to develop a second updated depletion demand schedule for CRSS version 6. Under typical conditions, this process takes about one year.

Given these modeling and timing constraints, Reclamation used the best available Upper Basin CU&L data for the EIS modeling.

With respect to published materials related to drought science, see **Section 5.3.10** in response to hydrology choice.

With respect to independent peer review in accordance with Executive Order 14303—Restoring Gold Standard Science (May 23, 2025) and the U.S. Department of the Interior Information Quality Guidelines Pursuant to Section 515 of the Treasury and General Government Appropriations Action for Fiscal Year 2021, Reclamation implemented a peer review process for the EIS. All models used for analysis went through a peer review process by the responsible agency. Reclamation conducted a peer review of the CRSS hydrological model, and the EIS went through a two-phase review process: (1) cooperating agency peer review of the preliminary Draft EIS and (2) an independent peer review of the Draft EIS. Results from the former were incorporated in the Draft EIS, and the results from the latter are included in the Final EIS. Peer review plans and reports for Reclamation generated products are available at Reclamation's Quality of Information Peer Review website.

For discussions about Lower Basin tributary CU&L and evaporation, see **Section R.3.7**.

For discussions about initial and hydrologic conditions see **Section R.3.10**.

R.3.21 Connected Actions and Cumulative Effects

Theme Summary

Commenters requested that alternatives disclose connected actions and operational details sufficient to support meaningful public and decision-maker review. Commenters asserted that the cumulative effects analysis is overly qualitative and incomplete, and requested expanded treatment of connected and indirect effects within Reclamation's purview. Specific requests included more comprehensive socioeconomic and public-health impacts, groundwater resources, and associated impacts such as depletion, subsidence, and water quality. Commenters also asked Reclamation to address how other foreseeable actions, such as urban growth, land use changes, and water-management projects, could contribute to cumulative effects.

Response

The EIS considers connected actions consistent with NEPA and regulations, focusing on impacts that are reasonably foreseeable from the proposed action and alternatives within the defined area of analysis and within Reclamation's authority.

As described in **Section 3.14.1.2**, cumulative effects analysis such as the potential socioeconomic consequences or impacts to local groundwater supplies due to shortages occurring in the municipal and industrial sector were qualitatively assessed since it was not known to what degree a specific economic sector considered a municipal and industrial use would be affected. The effects on individual cities or communities are indeterminate for various reasons. Each city or community has a different mix of water supplies, and in most cases, has formulated a shortage or drought response plan that is specific to their respective community. Also, individual response plans typically include varying combinations of demand-side and supply-side actions, and these differ by community. The use or acquisition of other water supplies and development and implementation of response plans would vary according to then-current state, tribal, and local laws, regulations, policies, or governing board or council actions, which are outside of Reclamation's jurisdiction.

Further, Reclamation is not required to consider environmental effects, including ecological, aesthetic, historic, cultural, economic, social, local custom and cultural, and health effects, from other projects that (1) are separate in time or place from the project at hand, (2) fall outside an agency's regulatory authority, or (3) are carried out independently by third parties. Ultimately, "where an agency has no ability to prevent a certain effect due to its limited statutory authority over the relevant actions, the agency cannot be considered a legally relevant 'cause' of the effect." (516 DM 1 - DOI NEPA Handbook 2026).

Additional information on connected actions and cumulative impacts on specific resources is provided in the resource themes below (**Sections R.3.26-R.3.41**).

R.3.22 Decision-Making under Deep Uncertainty and Approach to Analysis

Theme Summary

Commenters ask Reclamation to provide clearer explanations and figures for the DMDU analysis.

Commenters note that, in robustness analyses, alternatives do not meet important performance levels in 100 percent of hydrologic futures, and commenters ask if such results indicate none of the alternatives are robust.

Commenters ask Reclamation to focus on drier conditions and remove the mid and high initial condition scenarios.

Commenters ask Reclamation to attribute various performance outcomes to different operational components.

Response

We agree with commenters that the Draft EIS was insufficient in the description and interpretation of results. To address this, explanations have been improved for clarity throughout **Chapter 3** and the technical appendices. The vulnerability analysis figures have been updated with a new legend to aid interpretation, and the descriptions of the results have been improved.

Due to recent hydrologic conditions and reservoir storage, the analysis has been updated by removing the middle and high initial reservoir storage scenarios. The Final EIS considers only the low initial condition scenario.

Critically, Colorado River hydrology is highly variable year-to-year; the severity, frequency, duration, and sequencing of future hydrology is unknown; there is no consensus in the scientific or planning communities on how to characterize future hydrology probabilistically; and the types of hydrologic futures that are most relevant for evaluating critical system risks varies across alternatives, by resource, and often by individual analyses within a resource. Due to this deep uncertainty and high degree of inter-resource variation, a tailored ensemble of dry hydrology traces would be insufficient to analyze risks to all resources in this EIS.

The DMDU framework therefore analyzes a broad range of hydrologic conditions. The set of 400 hydrologic traces intentionally includes severely dry and wet traces (well outside the range of what

has been observed in the past) such that every alternative can fail critical performance goals (i.e., results in undesirable performance) in some percentage of futures. This is necessary so that, in vulnerability analysis, the expected hydrologic tipping point between preferred minimum performance and undesirable performance can be identified. Then, the vulnerability results, in combination with the reference hydrology, are used to interpret these results with the DMDU decision framework. Notably, descriptions of vulnerability results have been improved with concise conclusions about the alternatives. For example, this alternative [the Representative Preferred] is not likely to be vulnerable in the next 10 years because these conditions have not been observed and they occur in fewer than 10 percent of traces in the Drying with Variability Ensemble, which represents how hydrologic conditions may change in a warmer future' (see **Figure TA 4-3**). Please also refer to **Section 3.2.6**, **Appendix E**, DMDU Overview and Approach, and **Appendix F**, Approach to Hydrologic Uncertainty, for more information.

Regarding the presence of wet conditions in the 400 hydrologic traces, it is critical to understand the types of hydrology that result in undesirable performance that can occur under moderate or high reservoir conditions, such as cooler water temperatures that inhibit the growth and reproduction of native fish species (**TA 8**, Biological Resources – Fish and Other Aquatic Species), the availability of sediment for beach building in the Grand Canyon (**TA 5**, Geomorphology and Sediment), and use of the Glen Canyon Dam and Hoover Dam spillways (**TA 15**, Dams and Electrical Power Resources).

Simultaneously, Reclamation acknowledges that dry conditions pose significant risks. Vulnerability analysis identifies the specific dry conditions that are problematic for each alternative, then it compares those conditions to recent historical observations and plausible conditions under a drying future (the Drying with Variability reference hydrology). Further, results for the Representative Preferred alternative focus on Dry and Critically Dry conditions, and the 10-year tradeoff analysis for all alternatives in **Figure ES-5** focuses on conditions similar to and drier than recently observed. The Final EIS also frames the interpretation of results by explaining in **Chapter 3** that "Recent history combined with the increasing temperature trend, which is associated with lower streamflow, suggests that focusing more on the Average and Dry categories is warranted. However, Critically Dry conditions have been observed and could become more common".

A piece-wise sensitivity analysis of all or most operational elements to support an extensive attribution analysis was not practical due to the number of alternatives, number and complexity of operational elements, and associated modeling requirements. However, throughout the analysis there are opportunities to consider the impacts of different elements. For example, the influence of conservation pools on reservoir levels is demonstrated in **TA 3-16** and **TA 3-17** and on shortages in **Figure TA 4-5**. A comparison of Lake Mead elevations in **TA 3-17** without conservation pools demonstrates the relative effectiveness of different maximum shortage volumes. **Figure TA 4-6** was also added in the Final EIS to show the impacts of conservation pools on dead pool-related delivery reductions.

R.3.23 Water with Mexico

Theme Summary

Commenters emphasized the need for formal binational engagement, a shared responsibility for 1944 Water Treaty deliveries between the Upper and Lower Division States, and the inclusion of Mexico's participation in water delivery reductions alongside water conservation opportunities. Commenters caution that water delivery reductions from yet undetermined agreements with Mexico pose analytical risk and request the integration of the impacts of salinity compliance (i.e., Minute 242) into modeling and decision criteria.

Response

The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State. The modeled annual depletions in water deliveries to Mexico include modeling assumptions for reductions in water deliveries to Mexico and deferred deliveries that are available to Mexico for future delivery. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. Within this Final EIS analysis, the assumptions used for reductions in water deliveries to Mexico applied a fixed 16.67 percent of any total shortages applied to the Lower Basin, as well as any dead pool-related reductions. This assumption was applied uniformly across all alternatives, including the No Action Alternative. This percentage is computed by taking the ratio of Mexico's allotment to the sum of the Lower Basin U.S. apportionments and Mexico's allotment (1.5 maf/(7.5 maf + 1.5 maf) = 0.1667 or 16.67 percent) and ensures that the water delivery reductions to Mexico are proportional to the shortages to the U.S. users in the Lower Basin.

Both the Draft and Final EIS include a comparative assessment of the long-term implications of the proposed alternatives on salinity levels reaching both the Imperial Dam and the Northerly International Boundary. Regarding compliance with the obligations of Minute 242 to the 1944 Water Treaty with Mexico, the modeling reflects one explicit assumption for the volume of pumped groundwater that can be used to meet Mexico's delivery while complying with Minute 242. If the volume of pumped groundwater that can be used to meet the delivery requirement has to be reduced, absent any binational agreements to address salinity impacts, then there might be additional impacts to Lake Mead. The actual impacts to Lake Mead would depend on complex operations below Imperial Dam, including the volume of pumped groundwater that could be used to meet Mexico's delivery while complying with Minute 242. A supplementary analysis was added to **Appendix N**, International Border Region of the Colorado River, to bound the potential impacts on Lake Mead, using two assumptions for the volume of pumped groundwater that can be used while operating to meet the salinity requirement specified in Minute 242.

R.3.24 Consultation: Biology/ESA

Theme Summary

Commenters seek ESA consultation concurrent with NEPA and completed before the ROD. They request that the Biological Assessments (BA) focus on dry and critically dry scenarios and that the

Biological Opinions (BO) address specific river reaches and operational effects. Commenters also request a clearer and side-by-side analysis of how alternatives may affect listed species under the ESA, critical habitat, and conservation areas, including those associated with the GCPA and Lower Colorado River Multi-Species Conservation Program (LCR MSCP). Additional requests include explicit linkage of elevation and release patterns to ecological effects, improving analysis of impacts on conservation areas and habitats, and identifying mitigation or adaptive management measures that could address potential impacts under varying hydrologic conditions.

Response

The EIS evaluates potential impacts on fish and wildlife, including ESA listed species and species covered by the LCR MSCP, using the best available scientific information and modeling approaches appropriate for basin-scale analysis under uncertain future hydrologic conditions. Species covered by the LCR MSCP are included as special status species in the EIS. The analysis uses a DMDU framework to evaluate potential effects across a range of hydrologic scenarios. Because future river flows, habitat conditions, and species responses are highly uncertain, the analysis relies on modeled system outcomes rather than predicting impacts for specific species at individual locations. The EIS acknowledges that resource tradeoffs may occur under different alternatives and scenarios.

The purpose of the EIS is to evaluate and compare environmental consequences for each alternative under NEPA. Providing side-by-side comparisons with the ESA, the LCR MSCP, or the GCPA is not an objective of this EIS, as those authorities operate under separate statutory and regulatory processes. The relative impacts of alternatives on ESA listed and other special status species and critical habitat is assessed in **TA 8**, Biological Resources – Fish and Other Aquatic Species, and summarized in **Figure TA 8-31** for aquatic species, **TA 9,** Vegetation Including Special Status Species, and **TA 10,** Terrestrial Wildlife Including Special Status Species for terrestrial habitat type, vegetation, and associated wildlife. ESA compliance, including evaluation of incidental take and conservation measures, occurs through the Section 7 consultation process that Reclamation is working through with the U.S. Fish and Wildlife Service (FWS). Reclamation coordinated with FWS and other agencies during the development of the EIS.

Reclamation has multiple existing ESA consultations aligned with the Upper Basin and Lower Basin programs. In the Lower Basin, ESA analyses and incidental take are covered and permitted through the LCR MSCP Section 7 BOs/Section 10 Habitat Conservation Plan. The most recent consultation between Reclamation and the FWS occurred in 2024. This consultation provides full analysis and coverage through January 31, 2028, for reductions in flow from Hoover Dam up to 3.0 maf. Reclamation and the LCR MSCP are currently developing a BA and a Habitat Conservation Plan permit amendment to ensure adequate analysis and coverage for the range of operations associated with the length of the EIS. As described in the document, the operational plan for Hoover Dam is not anticipated to exceed the flow coverage analyzed in the 2024 BO.

Additionally, a BA is being prepared to determine whether the Preferred Alternative may affect listed species in the Upper Basin (from full pool of Lake Powell to Pearce Ferry Rapid). This BA may include Conservation Measures that lessen the impact of the action on listed species. The FWS will then issue a BO determining whether the action is likely to jeopardize the continued existence of listed species or destroy or adversely modify critical habitat. If jeopardy or adverse modification is

determined, a Reasonable and Prudent Alternative will be developed with appropriate measures and Conservation Recommendations.

R.3.25 Consultation and Coordination

Theme Summary

Commenters recommended broadening consultation and coordination to include all affected governments and user groups, including tribes; engaging other federal departments to address national-scale consequences. Commenters also stated that there was inadequate consultation on the preferred alternative.

Response

Reclamation conducted extensive public outreach, held public scoping meetings and meetings on the public Draft EIS, and consulted formally and informally with representatives from the cooperating agencies, Basin States, tribes, non-governmental organizations, and other interested parties to obtain input on the EIS. Reclamation reached out to other federal agencies with jurisdiction or special expertise to participate as cooperating agencies in this process. Additional details on this outreach are provided in **Chapter 4**. Reclamation will continue to coordinate future operations with affected stakeholders as appropriate.

For additional information regarding consultation on the Preferred Alternative, see **Section R.3.16**, Decision Process.

R.3.26 Air Quality

Theme Summary

Commenters stated that the Draft EIS and supporting technical appendices do not sufficiently assess air quality impacts, particularly at the community scale. Commenters requested that the air quality analysis expand its geographic scope to include impacts on the Salton Sea, Coachella Valley, and Imperial Valley. They asked for additional analysis of increased dust emissions associated with fallowing, as well as a more robust discussion of greenhouse gas and climate change-related effects. Commenters were also interested in the risks associated with increased emissions from low reservoir elevations.

Response

Reclamation acknowledges that reductions in water deliveries under the alternatives could result in increases in fallowed agricultural acreage and that, under certain conditions, fallowed lands may contribute to fugitive dust emissions. The Final EIS has been revised to expand the discussion of the relationship between fallowed agricultural lands and potential air quality impacts. Specifically, **TA 7**, Air Quality, now incorporates a screening-level evaluation of fugitive dust emissions from fallowed acreage using generalized emission factors derived from U.S. Environmental Protection Agency guidance (AP-42). This addition provides a representative range of potential PM_{10} emissions per acre of fallowed land. The Final EIS further clarifies the relationship between the air quality analysis and the fallowed acreage estimates presented in **TA 16**, Socioeconomics. Due to uncertainty in the location and extent of fallowing, the analysis remains regional rather than site-specific, which

is consistent with NEPA requirements. For more information on the geographic scope, see **Section R.3.19** theme response.

The Draft EIS addresses climate projections through hydrologic modeling that reflects observed and projected reductions in flows. The analysis evaluates how these conditions influence reservoir elevations, and hydropower generation. NEPA does not require attribution of specific hydrologic changes solely to climate trends where those effects are already embedded in the modeling framework. The analysis uses operational thresholds (e.g., minimum power pool elevations) as proxies to evaluate air quality and greenhouse gas impacts. Specifically, the shoreline exposure and associated emissions metrics are based on conditions corresponding to minimum power pool elevations. Accordingly, the Draft EIS takes a reasoned and technically supported approach to evaluating reservoir conditions, climate-related stressors, and associated air quality impacts. Additional figures showing long-term reservoir elevation trends have been added to strengthen the analysis.

The Technical Appendices include a comprehensive regional-scale analysis using established modeling methods, emissions estimates, and exposure indicators. The level of detail is appropriate for the scale and scope of operations considered in this EIS and supports comparison of alternatives. Community-by-community analysis is not appropriate because the project affects air quality at a broad, regional scale across multiple air basins. Additionally, the localized effects on air quality would depend on decisions by individual water users that are unknown and/or beyond Reclamation's control, e.g., voluntary participation in conservation activities. The analysis instead relies on regional modeling, emissions estimates, and surrogate exposure indicators (such as $PM_{2.5}$ concentrations and shoreline exposure) to capture potential impacts. This approach aligns with NEPA guidance and avoids misleading precision that would result from attempting highly localized predictions given uncertainties in emissions, hydrology, and atmospheric processes.

R.3.27 Dams and Electrical Power

Theme Summary

Commenters requested that operations maintain protective elevations to ensure reliable hydropower at Glen Canyon Dam and Hoover Dam. They asked Reclamation to clarify minimum power pool constraints. There were requests to analyze the impacts on the hydropower market and rates, including the consequences for the Basin Fund. Commenters also emphasized the need to prioritize proactive infrastructure planning and ensuring reliable releases at low elevations. In addition, they requested evaluation of bypass options or phased decommissioning scenarios, as well as wear and maintenance needs under extended low elevations. Additional requests were made to clarify the legal status of hydropower's role relative to Compact compliance. Finally, commenters asked for an evaluation of additional upstream and downstream facilities, including the downstream safety implications of flow variability at Davis Dam and of extended low-flow operations at CRSP facilities.

Response

Reclamation recognizes the need to clarify minimum power pool and turbine operability constraints by evaluating how often, how long, and how severely reservoir elevations fall below key operational

thresholds under different management approaches. **TA 15,** Dams and Electrical Power Resources, provides figures such as **TA 15-13**, illustrating how frequently Lake Powell remains above elevations necessary for sustained turbine operation, while **Figures TA 15-11** and **TA 15-6** show how turbine availability and generating capacity at Lake Mead/Hoover Dam decline as reservoir levels decrease. Together, these results demonstrate that protective elevation thresholds are used as risk-screening tools to understand infrastructure vulnerability and operational tradeoffs under uncertain future conditions, rather than as fixed operational requirements that dictate reservoir management. Operations and management plans are ongoing and evolving to the conditions of lowered water elevations.

Within **TA 15**, **Section TA 15.1.3** evaluates the infrastructure conditions and operational capabilities of the dams analyzed in this study. Reclamation utilizes the Dam Safety Priority Rating (DSPR) system at all dams evaluated in this analysis to conduct routine monitoring, support maintaining infrastructure, and identifying any potential risk. Under this system, Glen Canyon Dam and Hoover Dam were rated as a DSPR 5 category, indicating a low-priority level with normal urgency of action. This reflects that no immediate safety concerns have been identified. Davis Dam and Parker Dam were equally classified as a DSPR 4 Category, indicating a low urgency of action. Both dams were magnitude below Reclamation's PPG threshold. Both dams were determined to be in good overall condition and do not display any risks to safety.

Extended low-flow operations have been modeled by the Western Area Power Association at CRSP facilities, and potential effects on the Upper Colorado River Basin Fund. Concepts such as bypass construction or phased decommissioning represent separate, long-term infrastructure planning considerations that would require independent engineering evaluation, legal review, and project-specific environmental analysis outside the scope of this EIS.

Rate impact analyses have been developed to help evaluate how forecasted hydrologic and operational outcomes may influence market conditions and financial pressures under sustained low-storage scenarios at dams evaluated in this study. Updated modeling for Glen Canyon Dam and Hoover Dam, with clarifying language, is available in the Final EIS and **TA 15** addressing Wholesale Rate Analysis, Power Marketing, and, for CRSP and Glen Canyon Dam, discussion of considerations for the Basin Fund.

R.3.28 Geomorphology and Sediment

Theme Summary

Commenters expressed support for establishing a maximum monthly release volume to reduce the potential for sediment scour. They also supported a requirement for HFEs to occur within a specified time period after sediment delivery thresholds are met. Additionally, commenters suggested adopting binding HFE criteria that are aligned with sediment conditions and timing that reflects a natural hydrograph. They requested expanded analysis of system-scale sediment balance and sediment processes within Lake Powell, including delta evolution, storage loss, and mobilization under low pools.

Response

Reclamation acknowledges the recommendations for a fixed monthly release limit to protect sediment for HFEs and fixed timing for HFEs. The EIS evaluates operational guidelines and strategies and recognizes that future operations must remain responsive to hydrology, system conditions, and applicable legal and operational requirements. Reclamation will use LTEMP guidelines, including the planning and implementation team process that helps assess monthly release volumes. Existing LTEMP guidelines were incorporated in the modeling for the EIS analysis, and modifications to the LTEMP framework are outside the scope of this analysis.

The EIS is focused on post-2026 guidelines and coordinated management strategies for Lake Powell and Lake Mead. A basin wide sediment management plan for the entire CRSP system would be a broader effort outside the scope of this EIS.

Since 1963, Lake Powell has lost approximately 1.8 maf (6.8 percent) of storage capacity (Root and Jones 2022), with most sediment deposited in upstream areas above elevation 3400 feet. As reservoir elevations decline under all EIS alternatives, sediment deltas in Glen Canyon National Recreation Area are increasingly exposed, eroded, and incised by river channels, particularly along the Colorado River and major tributaries. These processes are already documented in the EIS with respect to visual resources, shoreline conditions, invasive vegetation, and exposed sediment surfaces. Quantitative prediction of sediment redistribution under alternative reservoir levels would require a reservoir-scale sediment transport model, which does not currently exist for Lake Powell. While continued reservoir lowering is expected to increase delta erosion and downstream redeposition of sediment, this redistribution does not change total sediment volume. If deltaic sediments shift from upstream areas into deeper portions of the reservoir, the migration of such sediments is not expected to impact withdrawals from Glen Canyon Dam. While available data and modeling limitations constrain quantitative assessment of alternative-specific sediment behavior within Lake Powell, Reclamation has clarified in the EIS that Lake Powell has sufficient dead storage capacity to trap most incoming sediments, with only a small amount reaching areas near the Glen Canyon Dam. Thus, sedimentation is not projected to impact dam safety, power generation, or the sediment concentration of Glen Canyon Dam during the analysis timeframe of this EIS.

R.3.29 Hydrologic Resources

Theme Summary

Commenters requested an expanded quantitative groundwater analysis, including groundwater levels, pumping, subsidence, water quality, springs, alluvial aquifers, and secondary impacts from increased groundwater pumping to offset surface water shortages.

Commenters also requested analysis of daily flow, ramping, and timing effects in the Grand Canyon, and asked that the timing, frequency, and duration of resource impacts receive the same level of attention as whether impacts occur at all.

Additional comments addressed Upper Basin and Lower Basin conservation pools, requesting more detailed analysis of their effects and greater clarity on how conservation activities influence reservoir

storage, releases, and system water, including how often conservation tools are used and how they help mitigate risk.

Response

The EIS recognizes the role of groundwater in supporting surface water processes, ecosystems, and water supplies. Regional-scale changes to groundwater are complex and difficult to quantify without extensive data records and groundwater models, and current data on groundwater at a regional scale is limited in both scope and historical duration. As a result, groundwater conditions, including levels, pumping, and connectivity to surface waters, are addressed at a qualitative level where applicable. Where more recent groundwater data is available, it has been used to explore trends near Lake Powell (**Section TA 3.1.3**) and Lake Mead (**Section TA 3.1.6**), drawing on the Arizona Department of Water Resources' groundwater site inventory.

With respect to the timing, frequency, and duration of resource impacts, the metrics and thresholds used in this analysis reflect the most important dimensions of system performance without implying more certainty than is warranted. Including additional analysis of the timing and duration of impacts would emphasize outcomes that are highly dependent on the specific sequencing of future flows and would therefore be more speculative than the analyses presented in the EIS. Robustness figures presented in the EIS are broken out by decade to provide insight into how performance may vary over time, and the text describing these figures has also been revised for clarity in response to comments. Daily flow, ramping, and timing effects in the Grand Canyon, however, are outside the scope of this EIS.

With respect to conservation pools, analysis of the effects of conservation activity on Lake Powell and Lake Mead storage can be found in **Figures TA 3-16** and **TA 3-17**, respectively. This includes the effects of both Upper Basin and Lower Basin conservation mechanisms. Additional information on the conservation mechanism is provided in **Section R.3.8**, Lower Basin Conservation and Storage and Delivery of Conserved System and Non-System Water.

R.3.30 Indian Trust Assets

Theme Summary

Tribes expressed concerns that the Draft EIS does not adequately address the Federal Government's trust responsibility because there may be water shortages to tribes. Similarly, tribes expressed concerns about some alternatives not honoring their water rights, which may have senior priorities. Tribes commented that post-2026 operations must respect the U.S.'s fiduciary obligations: decreed, settled, and federally reserved tribal rights are trust property that cannot be impaired, reallocated, or subordinated through administrative guidelines. Commenters seek transparency, analysis of leasing and storage arrangements, and tools (i.e., conservation, storage, protection pools, etc.) that are voluntary, compensated, time-limited, and explicitly non-prejudicial. Tribes also noted that unquantified, undeveloped, or unused tribal water should remain attributed to tribes and not be presumed available to other users in modeling or converted to system water. Tribes noted that reductions in water allocations would reduce the ability of tribes to manage their own resources and be self-sufficient and would negatively impact culturally important farming activities. Some commenters desired more tribe-specific analysis and representation in published

figures and tables. Finally, some commenters stated that the potential socioeconomic impacts associated with potential impacts on Indian trust assets should be analyzed more thoroughly and for individual tribes.

Theme Response

Reclamation recognizes the importance of tribal sovereignty, tribal water rights, and Reclamation's trust obligations consistent with congressional directives. Reclamation also recognizes the wide range of tribal perspectives expressed in the comments. Reclamation's Proposed Federal Action would be adopted and implemented consistent with the Law of the River, as explained **in Section 1.2**. Some components of the alternatives analyzed are within Reclamation's existing authorities, and some are outside existing authorities, as explained further in **Section 2.3** and therefore Reclamation would need additional agreements or other authorities to implement some of the analyzed operations. The assumptions used in Shortage Allocation Models and Alternative Distribution Models are not intended to represent current or future policy with respect to shortage sharing or to limit Secretarial discretion to distribute shortages, as noted on Page C-5 of **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation.

Tribal participation in any potential conservation pools would be voluntary; any modeling assumptions regarding participation in potential conservation pools are for the purposes of modeling only and are not binding, as further explained in **Chapter 2**.

Tribe-specific modeling results related to tribal water deliveries or shortages to tribal entitlements are available for the Shortage Allocation Models and Alternative Distribution Models (see **Appendix C**). In the technical appendices, the DMDU analysis was not applied to any individual users, including tribes. This approach to analysis is appropriate given the level of uncertainty in hydrology and distribution of impacts, and because entitlement-specific results are provided in **Appendix C** for the full range of modeled shortages. The DMDU analysis is designed to provide representative information to the public to compare the modeled frequency of shortage events to groups that experience similar impacts due to water entitlement priorities. This is not intended to imply that Reclamation believes the impacts are the same to all water users in a priority group. Reclamation recognizes that potential impacts on Indian Trust Assets, particularly potential reductions in water deliveries, could have adverse socioeconomic impacts to tribes. **TA 16**, Socioeconomics, includes discussion of potential changes to agricultural and recreational economies, as well as broad negative socioeconomic consequences that are representative for tribes and others. Because of unique circumstances for each tribe, the potential socioeconomic impacts would vary by tribe but are captured within the range of impacts identified in the Final EIS.

Reclamation intends that any new tools (i.e., conservation, storage, protection pools, etc.) would be voluntary and non-prejudicial to a tribe's ability to develop and use its entitlement. Additionally, for tribal water entitlements, the operational guidelines do not lose, forfeit, or abandon the corpus of the trust asset. The trust asset would be administered as defined in the statute, decree, and/or contract defining and establishing the entitlement, including any conditions relating to the obligation of the U.S. to deliver water subject to availability under the provisions of Federal law, including the Colorado River Compact, the BCPA, and the Consolidated Decree in *Arizona v. California*. Shortage administration of the entitlement would not limit greater future deliveries to tribes under improved

hydrology in normal or surplus Colorado River conditions, nor would it alter the applicable authority that defines the entitlement. Nor do the guidelines alter or amend any Indian water rights settlements or decrees, nor preclude or limit future Indian water rights settlements. Nothing in the analysis should be construed to limit ongoing or future quantification or development of tribal water rights.

R.3.31 Population and Land Use

Theme Summary

Commenters stated that the Draft EIS does not adequately explain how modeled reductions in domestic (municipal) water deliveries, particularly in Arizona and other Lower Basin municipal service areas, could affect population- and land-use-related outcomes, including concrete economic and social consequences. Commenters stated that the Draft EIS presents modeled delivery reductions but does not adequately explain what those reductions could mean for specific industries and users, development, housing, essential services, operations, adaptation efforts, and broader socioeconomic conditions. To reflect the wide-ranging themes raised by commenters and support efficient cross-referencing to summary responses, the discussion is organized using subheaders.

Development, housing, and growth plans: Commenters stated that reduced reliability of domestic water delivery could constrain residential and commercial development and affect housing supply in communities. Commenters emphasized the role of planning and regulatory requirements for reliable water supply and stated that reduced domestic water reliability could affect the ability of communities to meet existing plans for growth and development.

Existing communities and essential services: Reduced reliability of domestic water delivery could affect existing residents and essential services, including potable water, sanitation, fire protection, and other critical community functions. Commenters also raised concerns that an abrupt or severe domestic shortage could occur and impact essential services.

Infrastructure and operational thresholds: Municipal systems and conveyance/treatment infrastructure and distribution systems may not be designed to accommodate abrupt or deep reductions, and that short-duration disruptions can create operational challenges that differ from long-term average conditions. Commenters highlighted operational thresholds and system constraints and requested clearer discussion of how infrastructure constraints could affect community outcomes, particularly under extreme Shortage Conditions.

Adaptation capacity: Several commenters highlighted that adaptation capacity varies widely by provider and location, noting that while conservation and portfolio management can reduce vulnerability, other responses may be limited by physical availability, legal/jurisdictional constraints, cost, and the time required for planning, permitting, financing, and implementation.

Conservation and demand: Some commenters emphasized that population and land use are not direct proxies for water demand and that conservation and demand management can decouple water use from population growth. Others noted that existing conservation efforts and remaining

conservation potential vary by community, affecting how shortages may translate into land-use-related outcomes.

Model interpretation and limitations: Some commenters questioned how domestic deliveries are modeled and how results are interpreted and requested a clearer explanation of assumptions and limitations. Commenters also raised concerns about how the analysis treats extreme conditions and key thresholds and how such conditions could affect municipal reliability and community outcomes.

Secondary effects: Commenters requested more explicit consideration of secondary effects, including economic pressures, housing affordability, local tax base implications, land conversion pressures, and impacts on public services and community well-being. Some commenters also described indirect pathways tied to substitution (e.g., increased reliance on groundwater and associated depletion/subsidence/water-quality concerns) and broader community consequences.

Economic analysis: Many commenters also requested more robust, quantitative analysis of economic impacts on municipal and industrial sectors. Commenters requested Reclamation implement a range of approaches to quantify domestic water delivery impacts, including but not limited to, macroeconomic and regional economic impact analysis; sector-specific impact analysis; municipal- or utility-level economic analysis; housing and development quantification; infrastructure cost and damage estimates; public health and essential services quantification; adaptation cost and feasibility analysis; distributional or equity impact analysis; national or supply-chain impact analysis; and temporal and risk-based quantification.

Agricultural Lands Use: Commenters requested review of baseline data related to irrigated lands. In addition, they requested additional information regarding impacts on the agricultural system as a whole. Some commenters requested information pertaining to Upper Basin geographies as well as analysis of groundwater as a replacement source and potential for crop-switching.

Theme Response

Development, housing, and growth plans: The Final EIS has been revised to clarify that potential impacts could include changes to planning assumptions for water supply related to residential and commercial development and links the discussion to modeled delivery outcomes reported in **TA 4,** Water Deliveries.

Existing communities and essential services: The Final EIS has been revised to further clarify the potential qualitative impact from reduced municipal delivery reliability and recognizes that the feasibility and timing of adaptation vary by community. The Final EIS also recognizes that reduced municipal delivery reliability may affect essential services and public health and safety in some communities, particularly under severe or rapid shortage, and acknowledges that local emergency response planning and implementation actions would occur outside the scope of this EIS.

Infrastructure and operational thresholds: Reclamation recognizes that severe or abrupt delivery reductions can create operational challenges for conveyance and treatment systems and may affect service reliability depending on local infrastructure and operational constraints. The Final EIS

discusses these effects as qualitative pathways linked to modeled delivery outcomes; due to data limitations, it does not adopt facility-specific cost or damage estimates.

Adaptation capacity: The Final EIS recognizes that adaptation measures (e.g., new supplies, infrastructure, treatment, interconnections, and financing) can require substantial time and resources and may not be available on the same schedule for all communities. Accordingly, the Final EIS discusses adaptation feasibility qualitatively and focuses on the modeled frequency and magnitude of delivery reductions to characterize exposure, while noting that specific local project decisions would occur outside the scope of this EIS.

Conservation and demand: The Final EIS clarifies that population and land-use context are not treated as direct proxies for consumptive water demand. The Final EIS recognizes that conservation and demand-management measures can decouple water use from population growth and uses modeled shortage and conservation outputs to describe potential future conditions.

Model interpretation and limitations: The Final EIS acknowledges that Shortage Allocation Model and Alternative Distribution Model results reflect the modeled allocation frameworks and assumptions documented in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation, and do not represent all possible future place of use transfers or programmatic adjustments; therefore, the Final EIS uses **TA 4,** Water Deliveries, outputs to describe exposure and potential pathways for effects while identifying limitations where appropriate. The Final EIS also addresses key reservoir elevation thresholds and associated operational risks through the robustness and vulnerability analyses and resource-specific evaluations.

Secondary effects: Reclamation acknowledges that secondary effects may extend beyond direct domestic delivery changes. Where these outcomes are raised as reasonably foreseeable pathways, Reclamation addresses them qualitatively and, where appropriate, notes that such effects may be influenced by connected actions and cumulative effects outside Reclamation's direct authority, consistent with the framing in **Appendix R**, **Section R.3.21**.

Economic analysis: The Final EIS discusses domestic water delivery impacts as indicators of potential effects on communities and land-use related conditions by providing a qualitative discussion of municipal impact pathways using the modeled delivery-reliability and shortage outputs from **TA 4**, Water Deliveries, and documents limitations in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation. This approach recognizes that local outcomes depend on many factors outside federal operational control (including land-use decisions, provider-specific portfolio composition, and the timing and feasibility of adaptation measures).

Reclamation acknowledges concerns about potential effects on industrial and manufacturing sectors and other industries that rely on water supplies. The Final EIS has been revised to clarify the socioeconomic connection between modeled domestic water deliveries and employment sectors that rely on domestic water. It does not adopt sector-specific production or employment forecasts without consistent, comparable datasets and modeling inputs across the analysis area.

Agricultural Land Use: Baseline data was reviewed per comments and verified to accurately represent the cited data. Reclamation added an acknowledgment that other industries, such as

transportation and warehousing, manufacturing, which rely on the farming industry, could experience additional impacts. Broader economic relationships and indirect effects of changes in agricultural activity are addressed at a summary level in the Socioeconomics analysis (**Section 3.16**).

It is not possible to do a quantitative analysis on the impacts from switching to groundwater due to the uncertainties surrounding the quantity of groundwater switching, groundwater availability, and groundwater cost. See **Section R.3.19**, Scope, related to Upper Basin analysis.

The analysis addresses adaptive actions at a programmatic level to describe potential changes in land use patterns and consumptive water use. The Final EIS does not assume crop substitution is feasible or would result in sustained consumptive use reductions in all cases, and it does not distinguish quantitatively between crop substitution and fallowing in the land use analysis.

R.3.32 Recreation

Theme Summary

Commenters requested that the analysis be expanded to include recreation areas and resources beyond the defined analysis area, such as tributaries to the Colorado River, downstream national park infrastructure, and river-based recreation below Parker Dam. In addition, some commenters suggested reevaluating optimal flow ranges for whitewater boating based on available literature. Others requested further analysis of sediment-related hazards, including features such as perched channels and waterfalls, and their implications for whitewater recreation.

Response

Reclamation acknowledges the request to analyze additional recreational resources beyond those within the defined analysis area. The recreation analysis is consistent with the geographic scope defined in **Section 3.2.1**, Geographic Scope, of the EIS. Tributaries to the Colorado River are beyond the scope of the EIS. Recreational uses below Parker Dam are described in **Section TA 14.1.6**, **TA 14.1.7**, and **TA 14.1.8** of **TA 14**, Recreation. Flows below Hoover Dam are consistently low due to upstream diversions and delivery obligations. As a result, the range of operational changes evaluated across the alternatives would not meaningfully alter flow conditions in a manner that would measurably affect recreation opportunities in this reach. This rationale has been added to **TA 14**, Recreation.

The analysis relies upon available studies and the best available scientific information. These sources and literature were reviewed again, and it was determined that optimal flow ranges reported in the analysis were consistent with reported whitewater boater preferences.

In response to comments requesting analysis of sediment-related hazards to whitewater boating, Reclamation acknowledges that changing sedimentation dynamics resulting from low water have resulted in the creation of waterfalls, including the Piute Farms Waterfall and Pearce Ferry Rapid, which are acknowledged in the EIS as they relate to fish passage, and in **TA 14**, Recreation, in relation to whitewater navigability. Additional discussion regarding the potential development of another waterfall near Hite has been added to the EIS and **TA 14**.

R.3.33 Socioeconomics

Theme Summary

Note that comments related to concerns about economic analysis of municipal and industrial impacts are addressed under the theme summary and response in **Section R.3.31**, Population and Land Use. Comments related to concerns about impacts on economic conditions from changes in hydropower generation at Lake Powell are addressed under the theme summary and response in **Section R.3.27**, Dams and Electrical Power.

Commenters expressed concern that certain impacts on economic and social conditions from changes in agriculture were not included in the analysis, such as impacts on indirect industries, health and education services, the well-being of communities from potential increases in dust, and the national food supply chain. They recommended inclusion of additional sector-specific data sources and reports, additional costs that agricultural entitlement holders would incur, and recognition that agricultural decisions extend beyond simple fallowing of least-profitable crops. Some commenters are concerned that the analysis of socioeconomic impacts did not fully represent the magnitude and severity of impacts from changes in agriculture, especially when the results represented the fallowing of entire crops or acreages in a region. Other commenters requested consideration of conservation programs and adaptation measures, such as crop switching or conservation incentives, that would likely be used to lessen the reported impacts. Commenters expressed concern that the impacts on economic and social conditions from changes in agriculture were inaccurate because the analysis considered changes in water deliveries to agricultural entitlement holders, rather than changes in water deliveries to end users through certain leasing or transfer arrangements with the entitlement holders. Additionally, commenters requested that the results of the analysis be provided on a more granular scale than state-level.

Commenters further noted that recreation, particularly on Lake Powell, Lake Mead, and the Colorado River, represents an important economic contribution to the region and that a reduction in water in the reservoir would impact the tourism industry and the communities that depend on it. They also noted the economic importance of hydropower operations. Commenters also requested the addition of analysis related to recreation economic contributions associated with Lake Mohave and Lake Havasu and the vicinity of these areas.

In addition, commenters requested that Reclamation revise the socioeconomic discussion to include a more comprehensive analysis of the market and non-market river recreation values, as well as a review of non-market analysis to ensure consistency with other resource sections.

Theme Response

As discussed in **Section TA 16.2.1**, the modeling of impacts on economic conditions from changes in agriculture includes indirect impacts, which are impacts that result from changes in economic activity in industries that sell inputs to the industries that may be directly affected (for example, indirect impacts include changes in supply purchases made by agricultural producers or farmers). To provide context to the impacts analysis and address commenters' concerns, in the Affected Environment of the Final EIS, Reclamation added an acknowledgment that the farming industry supports other non-farming industries such as the transportation and warehousing, manufacturing

(including food manufacturing), and retail trade (including food and beverage and grocery stores) industries. In **Section TA 16.2.2** of the Draft EIS, there is a discussion about the impact on quality and access to nonmarket values and social conditions from changes in water allocation for irrigation entitlement holders, including impacts on affordable health and dental care. In the Final EIS, Reclamation added additional detail that there could be impacts on funding to support public services such as education and that these impacts could affect communities that rely on agriculture to support the economy and public services. Additionally, to address the concerns of commenters, in the Final EIS, Reclamation added an acknowledgment of the impacts on the national food supply chain due to changes in regional and local agriculture as well as the impacts on communities' quality of life from changes in dust associated with increased fallowed lands.

In the Final EIS, Reclamation referenced the reports provided and added a table with the new data source as well as added qualitative discussions on the assumption of fallowing lower valued crops first and the additional costs associated with fallowing that agriculture entitlement holders could incur.

To address the views that the analysis did not fully represent the magnitude and severity of impacts from changes in agriculture, in the Final EIS, Reclamation added additional detail highlighting the alternatives and shortage levels that would result in the potential fallowing of entire crops or acreages in a region.

To address commenters' requests to consider conservation programs and adaptation measures, Reclamation clarified that although the analysis does not assume funding or incentives for fallowing or conservation—as compensation measures are out of scope of this EIS—conservation programs and adaptation measures could be implemented in the future and would lessen the impacts discussed in the EIS. Additionally, as discussed in the Assumptions subsection of **Section TA 16.2.1** of the Draft EIS, Reclamation acknowledges that there could be crop switching rather than crop fallowing as a response to irrigation water shortages; however, the assumption that farmers would fallow irrigated crops in response to water shortages provides a bound to the analysis and any changes in this assumption would likely result in fewer impacts than discussed.

As discussed in the Assumptions subsection of **Section TA 16.2.1**, the Shortage Allocation and Alternative Distribution Models do not attempt to replicate arrangements where an entitlement holder leases its entitlement to other end users, and Reclamation cannot predict how the entitlement holder and its lessee(s) would respond to shortage. In the Final EIS, Reclamation added a note that if an entitlement holder leases water to another type of user, then a shortage in water deliveries would likely result in a financial impact on the entitlement holder as well as an impact from a reduction in water availability on the end users, similar to those impacts discussed for agricultural end users or discussed in **TA 17**, Population and Land Use, for municipal and industrial end users. The economic impact of the reduced delivery to the lessor would be to some degree mitigated by the financial payment from the lessee, while the benefits to the lessee of increased water delivery would possibly exceed the negative economic impact of reduced deliveries to the lessor.

Regarding the granularity of the analysis, the analysis was conducted commensurate with the level of decision making and based on the best available data at the time of the report. While the magnitude

of impacts might vary across entitlement holders, the nature and type of impacts that are discussed in the Draft EIS are consistent across all entitlement holders. In the Final EIS, Reclamation acknowledges that impacts on economic and social conditions from changes in agriculture across the alternatives vary across priority groups within each state, and Reclamation revised the results shown in **TA 16**, Socioeconomics, of the Final EIS to show impacts by priority group within each state as well as at the state level. Priority groups are used to represent the individual entitlement holders who would experience similar application of potential shortages under a given shortage scenario as defined in the Shortage Allocation Model and Alternative Distribution Model (**Appendix C**).

Recreation economic analysis was included in the Draft EIS at a level corresponding to that of a programmatic analysis (see **Section 3.16** and **TA 16** for economic contributions of recreation and tourism). Additional analysis related to economic contributions from recreation below Hoover Dam was not included as flows below the Dam are consistently low due to upstream diversions and delivery obligations. As a result, the range of operational changes evaluated across the alternatives would not meaningfully alter flow conditions in a manner that would measurably affect recreation opportunities or associated economic contributions in this reach.

R.3.34 Cultural Resources

Theme Summary

Commenters raised concerns about how reservoir operations and fluctuating water levels affect cultural and archaeological resources, noting that both shoreline exposure and re-inundation can damage or degrade sites. Commenters also called for improved transparency in the cultural resources analysis, including discussion of the limitations of survey coverage, clearer explanation of the preservation risk model, and continued government-to-government consultation with tribes to ensure culturally significant resources are accurately identified and protected.

Response

Reclamation acknowledges that changing water levels at Lake Powell and Lake Mead may expose previously undocumented cultural resources and that the potential effects of post-2026 operating Guidelines upon such cultural resources are not yet fully known, in large part because uncontrollable hydrology will determine such effects. The analysis incorporated available information from existing studies, prior consultation, cultural resources inventories, tribal input received during scoping and ongoing consultation, and resource analyses prepared for related Colorado River operation programs. As described in the Draft EIS cultural resource analysis, Reclamation conducted a Class I cultural resources inventory, consisting of a records search and literature review of previously identified cultural resources and prior survey efforts along the Colorado River corridor to help inform the analysis, identify data gaps and areas with limited survey coverage, and support development of the preservation risk model.

Section 106 of the NHPA requires that federal agencies consider the effects of their projects on historic properties and consult with stakeholders to avoid, minimize, or mitigate potential adverse effects. Reclamation, in consultation with the Arizona, California, Utah, and Nevada State Historic Preservation Offices, land managing agencies, tribes, and other consulting parties, is currently developing a programmatic agreement in accordance with Section 106 of the NHPA to address

potential adverse effects from post-2026 operating guidelines. The programmatic agreement is intended to establish a framework for ongoing identification efforts, consultation, monitoring, and treatment of historic properties that may be affected by the implementation of post-2026 operating guidelines. Reclamation will continue to engage with tribes and consulting parties throughout this process to help ensure that culturally significant resources are properly identified and considered.

R.3.35 Tribal Resources

Theme Summary

Commenters, including tribal representatives, stated that impacts on tribal resources should be analyzed at the tribe-specific level with explicit linkages between operational alternatives and ecological, cultural, subsistence, and spiritual uses, unique to each tribe. Commenters also request recognition of landscape-scale traditional cultural properties (e.g., Grand Canyon), emphasizing that these areas hold cultural, spiritual, and ecological significance extending beyond individual sites. Commenters recommended integration of Indigenous ecological knowledge and tribal perspectives into the analysis and decision-making process and further protections for trails and traditional water systems (e.g., acequias).

Theme Response

Reclamation recognizes that tribes maintain unique cultural, spiritual, ecological, and subsistence relationships with lands and waters within the Basin and that these relationships may vary substantially among tribes. The analysis in the Draft EIS was intended to evaluate potential environmental impacts at a programmatic operational level appropriate to the development of post-2026 operating guidelines and analyzed categories of potential effects associated with changes in reservoir elevations, hydrologic, and river operations across the Basin.

Portions of the affected area, including resources within the Grand Canyon corridor, are subject to ongoing consultation, monitoring, and treatment measures under the Glen Canyon Dam LTEMP Programmatic Agreement (PA). The LTEMP PA and corresponding Historic Preservation Plan provide an established framework for continued consultation with tribes and consulting parties regarding cultural resources and traditional cultural properties affected by operations associated with Glen Canyon Dam. Reclamation anticipates coordinating, as appropriate, with existing commitments and processes under the LTEMP PA to support continued consideration of effects in areas where authorities and agreements may overlap.

Reclamation acknowledges that certain areas of the Basin have been identified by tribes as traditional cultural properties or broader cultural landscapes that possess cultural, spiritual, historical, and ecological significance. Reclamation recognizes that the significance of these areas may derive not only from the presence of individual archaeological sites or historic properties, but from the interconnected character of the landscape as a whole, including natural features, traditional use areas, trails, water sources, and cultural relationships. Areas such as the Colorado River and the Grand Canyon have been identified by tribes as possessing this type of landscape-scale cultural significance, and Reclamation will continue to consider tribal input regarding these resources through ongoing consultation and related compliance processes, including Section 106 of the NHPA and coordination under existing agreements such as LTEMP in applicable areas.

Reclamation is grateful for the efforts tribes have made to consult on this EIS, and Reclamation remains committed to consultation with tribes throughout the NEPA and Section 106 processes and will continue to coordinate with tribes regarding culturally significant resources, traditional knowledge, and potential effects to tribal interests. Tribal input received through consultation helps inform Reclamation's understanding of culturally important places, traditional resource uses, trails, water systems, and other features and considerations that may not be fully captured through conventional archaeological or environmental review methods. Information provided through consultation, where appropriate and consistent with tribal confidentiality concerns, may inform future identification efforts, management strategies, and implementation measures. Impacts on vegetation, fish, and wildlife are addressed in other sections.

R.3.36 Vegetation

Theme Summary

Commenters requested a more comprehensive and transparent analysis of vegetation and wetlands, including a better definition of historic conditions, clearer explanations of modeled results, and updates to acres exposed since 2011. Commenters noted the lack of detailed information about where impacts would happen and how many acres could be affected. Commenters also requested that additional information regarding newly exposed side canyons around Lake Powell be added to the analysis.

Response

The EIS was updated to address comments regarding wetlands and vegetation to clarify the analytical approach used to establish baseline conditions and effects under each alternative. The vegetation analysis evaluates marsh and woody riparian vegetation using the DMDU framework to assess potential impacts across alternatives under highly uncertain conditions. Given the high level of hydrologic uncertainty, it is difficult to predict under each alternative exactly where or how much habitat might be lost or gained over the 34-year time period. Therefore, results are provided as a comparative analysis rather than species-specific or site-specific evaluations. Where long-term monitoring data is available, the analysis includes modeled estimates of suitable habitat for marsh and woody riparian habitat. Additional information was added to the EIS to further address impacts to newly emerged side canyons around Lake Powell.

R.3.37 Visual Resources

Theme Summary

Commenters requested additional analysis of the visual impacts related to dead pool conditions at Lake Powell, recognition of re-emerging side canyons becoming available for recreation access, and broader inclusion of "attraction features" or other viewing locations in the analysis.

Response

Text was added discussing the re-emergence of side canyons, directing readers to the Recreation section regarding public access related to reservoir inundation, and clarifying the "attraction features" concept, with additional viewers (viewing locations) currently described under Issue Statement 2. The concept of Lake Powell reaching dead pool elevation is described under Issue

Statement 3 as the effects on visual character would occur from water being unable to flow past Glen Canyon Dam, affecting landscape character along the Colorado River and downstream, therefore no additional analysis has been included.

R.3.38 Water Deliveries

Theme Summary

This section summarizes comments on the framing and analysis of the water deliveries section of **Chapter 3** and **TA 4**, Water Deliveries. Comments related to the volume and distribution of Lower Basin shortages, distribution of dead pool-related reductions, and the use of conservation mechanisms and their interaction with shortages are addressed in **Section R.3.7**, Lower Basin Shortage and Use, and **Section R.3.8**, Lower Basin Conservation and Storage and Delivery of Conserved System and Non-System Water.

Commenters requested additional information on how evaporation associated with conservation mechanisms is assessed. Commenters also requested additional information and greater transparency regarding the modeling assumptions and methodologies used to evaluate water deliveries and reservoir operations, including the reliability of water deliveries under low-flow conditions. In addition, commenters noted that dead pool-related reductions were mostly separate or absent from analyses across multiple resources and that the analysis should include information about the frequency and duration of such reductions to better demonstrate the effectiveness of operational elements across alternatives. Finally, commenters requested greater transparency regarding the minimum water deliveries available to municipal users to meet health and safety needs.

Theme Response

Reclamation acknowledges the comments requesting additional information and greater transparency regarding the evaluation of water deliveries and reservoir operations. **TA 4**, Water Deliveries, provides an overview of how water deliveries vary among the alternatives, including the effects of different shortage distribution approaches across the range of modeled hydrologic conditions. For more detailed information on how different shortage distribution methods represented by the alternatives affect water deliveries to individual water users by priority group, see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, which documents the modeling assumptions and results used to evaluate alternative approaches to distributing Colorado River water supplies under the alternatives analyzed in this EIS.

TA 4 has also been revised to improve transparency regarding the effects of conservation activity modeling assumptions on Lake Mead dead pool-related reductions (see **Figure TA 4-6**). Information describing the conservation mechanisms incorporated into each alternative, including the associated evaporation assessment, is provided in **Appendix B,** Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water. The volumes of water needed to meet municipal health and safety needs are highly variable depending on water user infrastructure, water supply portfolios, and many other factors. If more detailed evaluation of municipal health and safety deliveries becomes necessary in the future, Reclamation would conduct more targeted analyses and communicate the process and results to the public.

R.3.39 Water Quality

Theme Summary

Commenters requested additional information on salinity, including whether salinity impacts were considered for each alternative, and what thresholds were used to determine significance.

Commenters also requested clarifications on the description of perchlorate, including characterizing perchlorate in Las Vegas Wash flows to Lake Mead as an active and ongoing concern, removing the characterization of this contamination source as a point source, and clarifying the difference between the human health impacts associated with exposure duration to per- and polyfluoroalkyl substances versus perchlorate.

Commenters requested discussion or analysis of water quality concerns in the CAP system if deliveries are significantly reduced.

Commenters also provided general water quality comments that did not raise substantive issues requiring further response.

Response

Reclamation analyzed salinity under each alternative in **Chapter 3** and **TA 6**, Water Quality; therefore, no further changes were made to the salinity analysis.

The water quality section was updated to address concerns with the characterization of perchlorate in the EIS by noting the active and ongoing concerns with perchlorate in the Las Vegas Wash and its associated monitoring and mitigation. The water quality section was also updated to remove the description of perchlorate contamination at Las Vegas Wash as a point source and to define health impacts associated with perchlorate by its human health impacts associated with acute and intermediate exposure.

Reclamation updated **Section 3.2** to clarify the geographic scope for analysis. Reclamation also updated the methodology in the water quality section (**TA 6** and EIS **Section 3.6**) to clarify that the analysis does not include impacts on municipal users since operations of municipal water providers fall outside of Reclamation's regulatory authority and are carried out independently by these third parties. Reclamation delivers raw (untreated) water along the Mainstream and CAP, and Reclamation does not warrant the quality of Colorado River water deliveries. Groundwater in Arizona is governed by state law, which is generally outside of Reclamation's jurisdiction, with limited exceptions based in federal law. Therefore, analysis of economic impacts associated with water quality was not included in the EIS.

Reclamation did not update the EIS based on general water quality comments that did not raise substantive issues requiring further response; however, Reclamation considered these comments as part of the NEPA process.

R.3.40 Wildlife: Fish and Other Aquatic Species

Theme Summary

Commenters requested clearer analysis linking dam operations, such as flow timing, flow quantity, and release temperatures, to aquatic habitat conditions, including riparian change, erosion, and habitat complexity, that support native fish communities. Many commenters emphasized the importance of minimizing nonnative fish entrainment through Glen Canyon Dam and maintaining temperature conditions protective of native species while also supporting recreational fisheries and hatchery operations. Commenters also requested an evaluation of potential ecological effects under low-flow conditions through the Grand Canyon, including algal blooms, fish die-offs, and impacts on downstream wetlands. Additional comments recommended evaluating operational and infrastructure tools, such as reservoir elevation management, selective withdrawal, temperature control measures, barriers, and mechanical removal programs, to address invasive species risks and maintain ecological thresholds for fish and aquatic resources.

Response

The EIS evaluates aquatic habitat and fish resources using the best available scientific information and modeling approaches appropriate for basin-scale analysis under uncertain hydrologic conditions. Habitat analysis links reservoir elevation and river stage to fish habitat using stage-to-habitat relationships derived from scientific literature. These relationships connect water surface elevation to the amount and type of habitat available to fish. Surface area and longitudinal analyses were used to evaluate changes in habitat extent in reservoir and river environments, with interpretation supported by the DMDU framework. The technical appendix also describes how different lake elevations affect fish habitat by species and life-history strategies.

The EIS includes analysis of listed fish species and other species of concern, with descriptions of distribution and abundance, habitat, and life history provided in the technical appendix and Attachment. Important tributaries, such as the Little Colorado River and Havasu Creek, are also addressed for their significance to humpback chub populations.

The analysis relies on available studies, comparisons with historical flow conditions experienced by fish communities over the past several decades, species life-history information, and modeling tools such as the Smallmouth Bass Model. The analysis evaluates connections among flow, reservoir elevation, water temperature (where data are available), and the potential for nonnative fish entrainment at Glen Canyon Dam. Temperature thresholds used in the analysis include maintaining temperatures below 16 degrees Celsius to limit smallmouth bass reproduction as far downstream as the Little Colorado River and to support the rainbow trout population in the Lees Ferry reach, and above 12 degrees Celsius to support humpback chub downstream of the Little Colorado River.

The EIS evaluates alternatives prior to selecting a preferred alternative and identifies potential trade-offs among resources using the DMDU framework. Conservation measures and mitigation to address potential impacts on listed species, including risks such as nonnative fish entrainment, will be developed during the ESA consultation process through preparation of a BA for the selected alternative.

R.3.41 Wildlife: Terrestrial

Theme Summary

Commenters requested a more comprehensive and transparent analysis of wildlife and habitat impacts. They stated that the document underestimates or omits significant effects on endangered species, LCR MSCP species, migratory birds, amphibians, and other wildlife across key ecosystems such as the Lower Colorado River, Glen Canyon restoration areas, urban landscapes, and the Salton Sea. Overall, commenters requested expanded biological analysis, clearer disclosure of impacts, and stronger consideration of habitat protection and water management measures to support sensitive species.

Response

The EIS evaluates wildlife impacts based on impacts on vegetation, as determined through modeling exercises to identify where habitat may change compared to the interim guidelines period. Given the high level of hydrologic uncertainty, it is difficult to predict under each alternative exactly where or how much habitat might be lost or gained over the 30-year time period. Therefore, results are provided as a comparative analysis rather than species-specific or site-specific evaluations. Many requested actions are outside of the geographic scope or jurisdiction of the EIS.

R.4 References

Bureau of Reclamation (Reclamation). 2024. Technical Decision Memorandum – Establishment of Interim Operating Guidance for Glen Canyon Dam during Low Reservoir Levels at Lake Powell. U.S. Department of the Interior, Bureau of Reclamation. Internet website: https://www.usbr.gov/uc/DocLibrary/Memos/20240326-EstablishmentInterimOperatingGuidanceGlenCanyonDamLowReservoirLevels-TechnicalDecisionMemo-508-TSC.pdf\.

Root, J. C., and D. K. Jones, 2022. "Elevation-area-capacity relationships of Lake Powell in 2018 and estimated loss of storage capacity since 1963: U.S. Geological Survey Scientific Investigations Report 2022–5017". Internet website: https://doi.org/10.3133/sir20225017.

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Appendix S

Additional Description of Alternatives

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
1944 Water Treaty	1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2007 ROD	Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
AOP	Annual Operating Plan
Basin	Colorado River Basin
CCS	Continued Current Strategies
CRBPA	Colorado River Basin Project Act of 1968
CRSP	Colorado River Storage Project
CY	calendar year
DCP	Drought Contingency Plan
EIS	environmental impact statement
IBWC	International Boundary and Water Commission
ICS	Intentionally Created Surplus
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
LROC	Long-Range Operating Criteria
maf	million acre-feet
Mexico	United Mexican States
PPR	Present Perfected Right
Reclamation	Bureau of Reclamation
ROD	record of decision
Secretary	United States Secretary of the Interior
Upper Basin	Upper Colorado River Basin
U.S.	United States
WY	water year

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Appendix S. Additional Description of Alternatives

S.1 No Action Alternative

Under the National Environmental Policy Act, an action agency is required to describe and analyze a "no action" alternative in an environmental impact statement (EIS). The design of a no action alternative is highly dependent on whether the proposed action would be a wholly new activity or would be a part of ongoing or continuing actions. The proposed action for this Post-2026 process represents ongoing activities because the Bureau of Reclamation (Reclamation) has been and must continue to operate the system.

In developing the No Action Alternative, Reclamation carefully reviewed the No Action Alternative included in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 Final EIS; Reclamation 2007a). Consistent with that No Action Alternative, with refinements, Reclamation based the No Action Alternative in the Draft EIS on the operating guidance that was in place before the adoption of the Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 ROD; Reclamation 2007b) to provide a reasonable representation of how the system would continue to operate if no additional operating guidelines were adopted.

Before the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines) were in place, the basis for operations was the LROC, under which the Secretary made a number of determinations at the beginning of each operating year through the development and execution of the AOP, including the water supply available to users in the Lower Colorado River Basin (Lower Basin) and the annual release from Lake Powell. The Long-Range Operating Criteria (LROC) does not include specific guidelines for such determinations, so the outcome of the annual determination in any particular year in the future could not be precisely known. However, a reasonable representation of future conditions under the No Action Alternative is needed for comparison to each action alternative. The modeling assumptions used for this representation are consistent with assumptions used in previous environmental compliance documents, most recently the 2007 Interim Guidelines, with appropriate refinements. The assumptions used in the No Action Alternative are not intended to limit or predetermine the decision in any future Annual Operating Plan (AOP) determination.

Under this alternative, following the expiration of current domestic and international implementing agreements in 2026, Reclamation operations are assumed to immediately revert to the assumptions embedded in the No Action Alternative beginning October 1, 2026. This approach would represent a change from current operations (which are most closely captured in the Continued Current

Strategies (CCS) Comparative Baseline - see **Section 3.2.3**) but would not represent a decision by Reclamation to adopt a new set of long-term operating guidelines.

S.1.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

S.1.1.1. Shortage Conditions

In accordance with the Consolidated Decree and the LROC, the Secretary makes a determination each year as to whether the consumptive use requirements of mainstream users in the Lower Division States will be met under a Normal, Surplus, or Shortage Condition. The LROC specify that the Secretary will consider all relevant factors in making a shortage determination and list some of the factors to be considered. However, there is no specific guidance as to exactly when, how, or to whom reductions in deliveries would be made. Therefore, it is impossible to know exactly how the Secretary might make a shortage determination from year to year in the future.

The Consolidated Decree, the Colorado River Basin Project Act of 1968 (CRBPA), water delivery contracts, and applicable provisions of the Law of the River provide some guidance with regard to how shortages would be allocated in the Lower Basin (e.g., Present Perfected Right (PPR)[1] deliveries must be met without regard to state lines, California does not incur shortages until Arizona post-1968 contracts are reduced completely), but there are no specific guidelines in place to further inform the Secretary's decision with respect to how shortages or surplus might be shared by Arizona, California and Nevada, and water users in those states.

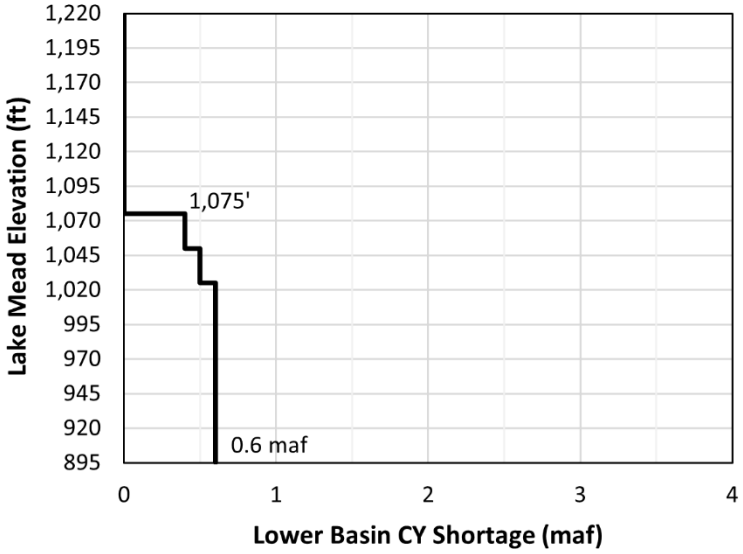
Considering the experience gained implementing shortages according to the 2007 Interim Guidelines, the elevations and volumes adopted in that ROD are assumed for this alternative. Operational zones are summarized below and shown in **Figure S-1**. The distribution of the shortages, summarized in **Table S-1**, would be based on the interpretation of priority from the Consolidated Decree and CRBPA;[2] not the distribution adopted in expiring guidelines. The shortage volume would be determined for the upcoming calendar year (CY) based on January 1 Lake Mead elevation.

- When Lake Mead is projected to be below elevation 1,075 feet and at or above elevation 1,050 feet on January 1, a shortage of 400.0 thousand acre-feet (kaf) would be imposed for that year.
- When Lake Mead is projected to be below elevation 1,050 feet and at or above elevation 1,025 feet on January 1, a shortage of 500.0 kaf would be imposed for that year.
- When Lake Mead is projected to be below elevation 1,025 feet on January 1, a shortage of 600.0 kaf would be imposed for that year.

[1] Certain Lower Basin Colorado River water rights are "present perfected rights" or "PPRs," which the Consolidated Decree quantified and defined as existing on June 25, 1929 (the effective date of the Boulder Canyon Project Act). PPRs are the highest priority Colorado River water rights.

[2] **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, describes assumptions associated with the Priority Shortage Allocation Model (SAM), which represents an interpretation of the lower Colorado River priority systems among and within the Lower Division states absent additional agreements.

Figure S-1
Shortage* Guidelines to Reduce Deliveries from Lake Mead, No Action Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to the United Mexican States (Mexico). Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty) or to represent current United States (U.S.) policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission (IBWC) in consultation with the Department of State.

Table S-1
Shortage Distribution*, No Action Alternative

Entity	Percentage of Total Shortages
Arizona	77.4
California	0
Nevada	5.93
Mexico	16.67
Total	**100**

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

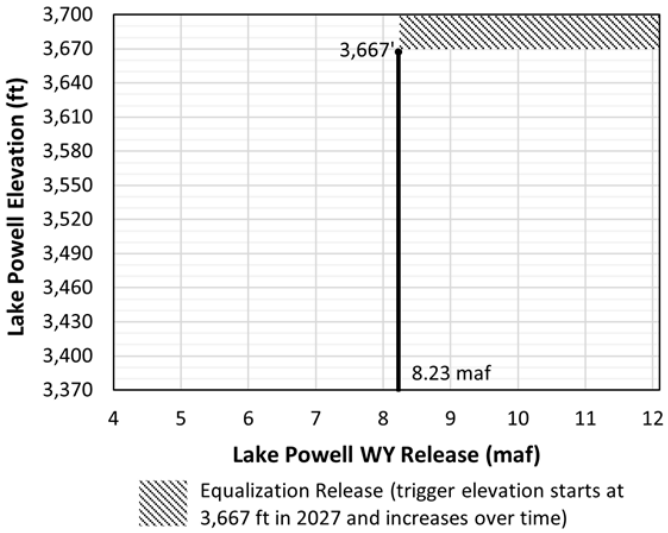
S.1.1.2. Surplus Conditions

Volumes above normal apportionment would be distributed only when criteria are met in Lake Mead for a 70R Surplus Condition[3] or a Flood Control Surplus Condition.[4]

S.1.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

The WY release volume from Lake Powell would be calculated based on the October 1 elevations of Lake Powell and Lake Mead using the curve depicted in **Figure S-2**. The curve is used to determine Lake Powell's releases in accordance with the LROC. Pursuant to the LROC, the objective is to maintain a minimum release of water from Lake Powell of 8.23 million acre-feet (maf) unless a higher release is required for equalization.

Figure S-2
Coordinated Operations of Lake Powell and Lake Mead, No Action Alternative



Article II(2) of the LROC states the "objective shall be to maintain a minimum release of water from Lake Powell of 8.23 [maf]." Reclamation recognizes that entities in the Colorado River Basin (Basin) have different legal positions regarding how this LROC statement incorporates other Law of the River elements to determine annual releases. The Secretary has expressly recognized that variation in releases of water above and below the minimum objective release of 8.23 maf can, in appropriate circumstances, be adopted (Norton 2005). The LROC expressly note that releases from Lake Powell pursuant to the LROC or any adopted guidelines "shall not prejudice the position of

[3] The 70R Strategy is a modeling approach used by Reclamation since the 1980s to understand the need to distribute additional water, and it was documented in the 2007 Final EIS. Under the strategy, a Surplus Condition is based on the system space requirement at the beginning of each year. Based on the 70th percentile historical runoff, a normal 7.5 maf delivery to the Lower Division States, the Upper Basin scheduled use, and Lake Powell and Lake Mead volumes at the beginning of the year, the volume of water in excess of the system space requirement at the end of the year is estimated. If that volume is greater than zero, a Surplus is declared.

[4] If flood control releases are anticipated to be required given the current inflow forecast, the Secretary declares Flood Control Surplus conditions for that year.

either the Upper or Lower Basin interests with respect to the required deliveries at Lee Ferry pursuant to the Colorado River Compact."

S.1.2.1. Primary Operations

If the October 1 elevation at Lake Powell is below the elevation specified by the equalization line for that year and spill avoidance releases are not required, a release of 8.23 maf would be made.

S.1.2.2. Coordination at High Elevations

A determination to potentially adjust releases from 8.23 maf for the purpose of equalizing storage in Lake Powell and Lake Mead would be made based on Lake Powell elevation using an extrapolation of the line adopted in the 2007 Interim Guidelines and documented in the 2007 Final EIS. This series of increasing Lake Powell elevations was developed as a translation of "602(a) Storage."[5] In 2027, equalization would be triggered at 3,667 feet; it would reach 3,698 feet in 2060 (the final year of the analysis period). A table showing specific years and elevations is included in **Appendix A**, CRSS Model Documentation. **Appendix J**, Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage, describes the 602(a) storage calculation that forms the basis for the equalization line from the 2007 Interim Guidelines. It documents the parameters used in the 2007 calculation, which are also used in this extension through 2060. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values. If Lake Powell is above the equalization elevation in any month, water year (WY) releases would be adjusted above 8.23 maf if needed to bring Lake Powell elevation down to the equalization line based on the 2007 Interim Guidelines[6] or to equalize storage between Lake Powell and Lake Mead to the extent practicable, whichever is reached first.

S.1.2.3. Infrastructure Protection and Other Considerations

While assumptions for adjustments to Lake Powell releases to forestall reaching physical elevation 3,490 feet have not been developed for this alternative, Reclamation maintains the authority to modify operations to protect Glen Canyon Dam infrastructure.

S.1.3 Storage and Delivery of Conserved System and Non-System Water

S.1.3.1. Lake Powell and Lake Mead Mechanisms

There would be no new mechanisms to proactively conserve and store water in Lake Powell or Lake Mead.

S.1.3.2. Treatment of Pre-2027 Intentionally Created Surplus

Intentionally Created Surplus (ICS) created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. Modeling

[5] CRBPA, section 602(a); LROC, section II(1). The 602(a) storage requirement specifies the amount of storage in Upper Basin reservoirs necessary to assure deliveries to the Lower Basin in compliance with the Compact without impairment to the annual consumptive use in the Upper Basin.

[6] For modeling purposes in this alternative, Reclamation intends that the equalization line concept used in the 2007 Interim Guidelines be applied and extended in the same manner as adopted in the 2007 Interim Guidelines with reference to 602(a) considerations.

assumptions for the timing of these deliveries can be found in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water.

S.1.4 Additional Activities Above Lake Powell

S.1.4.1. Upper Basin Conservation

No Upper Colorado River Basin (Upper Basin) conservation would be included.

S.1.4.2. Releases to Protect Glen Canyon Dam

While specific assumptions for releases from Colorado River Storage Project (CRSP) Upper Initial Units have not been developed for this alternative, Reclamation maintains the authority to operate these reservoirs to protect Glen Canyon Dam infrastructure.

S.2 Basic Coordination Alternative

The Basic Coordination Alternative was designed to be implementable without agreements among Basin water users regarding distributions of lower Colorado River mainstream shortages, storage and delivery of conserved water from system reservoirs, or other voluntary agreements.

Management of the Colorado River has to date been informed by negotiated stakeholder agreements. In the absence of such agreements, efficient and sustainable management of the reservoirs and system resources under an increasingly broad range of potential future hydrologic conditions would be more challenging than under historical operations and would result in a number of highly undesirable consequences for many users.

With or without new agreements, the U.S. Secretary of the Interior (Secretary) has the vested authority and responsibility to operate the System through coordinated operations, including the ability to respond to exigent and emergency conditions, pursuant to applicable federal law, the Decree, contractual obligations, and other elements of the Law of the River. Reclamation's description of how this alternative would be implemented relies on legal, operational, and engineering judgment regarding future operations under a broad range of hydrologic conditions.

While Reclamation has experience under high-flow conditions, including flood control operations, at Lake Powell and Lake Mead, Reclamation has not had to operate these reservoirs with extreme low-flow conditions imminently threatening critical infrastructure, which makes it difficult to predict operational outcomes. Reclamation would need to balance the needs of water users with infrastructure concerns in real time under such conditions.

S.2.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

S.2.1.1. Shortage Conditions

This alternative includes shortages of up to 1.48 maf, distributed based on priority (see **Table S-2**). The maximum shortage volume is set at a level estimated by Reclamation to ensure that an assumed minimum flow is available for infrastructure protection and delivery for municipal use by Central

Arizona Project (CAP) users and other Fourth Priority mainstream entitlement holders in Arizona when mainstream shortage is distributed by priority.

Table S-2
Shortage Distribution,
Basic Coordination Alternative

Entity	Percentage of Total Shortages
Arizona	77.40
California	0
Nevada	5.93
Mexico	16.67
Total	**100**

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

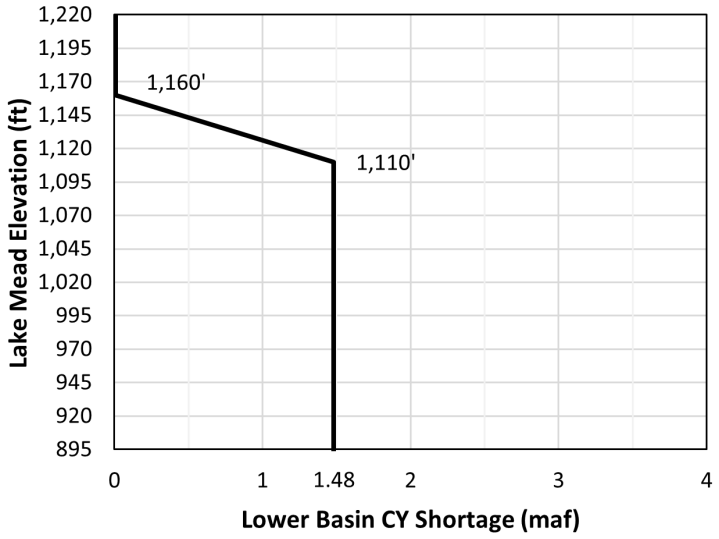
The shortage volume would be determined for the upcoming CY based on October 1[7] Lake Mead elevation. The shortage volumes are expressed as total Lower Basin shortage and include an assumption that the deliveries to Mexico are also reduced. The shortage guidelines are summarized below and shown in **Figure S-3**.

- When Lake Mead is at or below elevation 1,160 feet and at or above 1,110 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,160 feet increasing linearly to 1.48 maf at 1,110 feet.
- When Lake Mead is below elevation 1,110 feet, a shortage of 1.48 maf would be imposed for that year.
- When Lake Mead is approaching 1,000 feet, the Secretary would determine and implement additional measures as necessary to protect critically low elevations, consistent with the Law of the River.[8]

[7] For modeling purposes, assumptions regarding the use of projected or actual Lake Mead elevations to set operational conditions have been made. These assumptions are for modeling purposes only, and precise implementation details would be developed in a ROD.

[8] This alternative proposes that the Secretary may seek new authorities to implement additional measures to protect critically low elevations at Lake Mead including additional shortages to Lower Basin water users. The possible outcomes of such a process are unknown; therefore, for modeling purposes it was assumed that shortages of 1.48 maf would continue to be applied at Lake Mead elevations below 1,000 feet unless constrained by infrastructure. The Secretary would ensure appropriate consultation with Basin entities would occur consistent with the Law of the River.

Figure S-3
Shortage Guidelines to Reduce Deliveries from Lake Mead, Basic Coordination Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

S.2.1.2. Surplus Conditions

Volumes above normal apportionment would be distributed only when criteria are met in Lake Mead for a 70R Surplus Condition or a Flood Control Surplus Condition, see footnotes 3 and 4 for details.

S.2.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

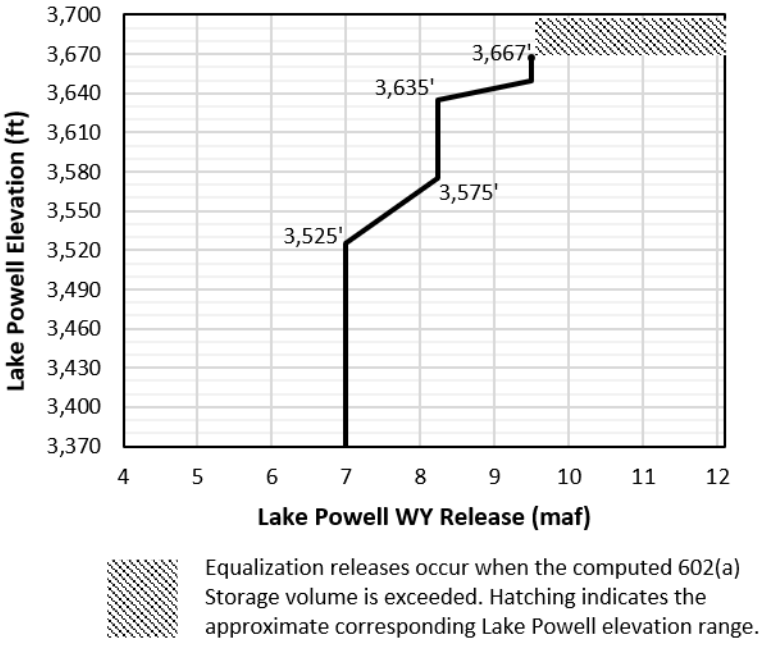
The WY release volume from Lake Powell would be based on flexible implementation of the LROC and provides for specified releases both above and below 8.23 maf. The 2007 Interim Guidelines, designed to implement the LROC for an interim period, incorporate such an approach. The operations summarized below and depicted in **Figure S-4** represent a systematic approach to releasing 8.23 maf while protecting high- and low-elevation infrastructure.

S.2.2.1. Primary Operations

- If the October 1 Lake Powell elevation is above elevation 3,650 feet and an Equalization determination has not been made, the WY release would be 9.5 maf.
- If the October 1 Lake Powell elevation is between 3,635 feet and 3,650 feet, the WY release volume linearly increases from 8.23 maf at elevation 3,635 feet to 9.5 maf at elevation 3,650 feet.
- If the October 1 Lake Powell elevation is between 3,575 feet and 3,635 feet, the WY release would be 8.23 maf.

- If the October 1 Lake Powell elevation is between 3,525 feet and 3,575 feet, the WY release volume linearly increases from 7.0 maf at elevation 3,525 feet to 8.23 maf at elevation 3,575 feet.
- If the October 1 Lake Powell elevation is below 3,525 feet, the WY release would be 7.0 maf.
- If on October 1 Lake Powell is projected to fall below 3,500 feet within the upcoming WY, Reclamation would consider additional measures as necessary to protect critically low elevations, consistent with the Law of the River.[9]

Figure S-4
Coordinated Operations of Lake Powell and Lake Mead, Basic Coordination Alternative



S.2.2.2. Coordination at High Elevations

A determination to potentially increase releases for the purpose of equalizing storage between Lake Powell and Lake Mead is made for the upcoming year if, on October 1, the net storage of all CRSP reservoirs exceeds the 602(a) storage volume, computed using the parameters from the 2007 Final EIS. **Appendix J**, Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage, describes the 602(a) storage calculation and documents the parameters used in the 2007 calculation, which are also used in this alternative. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values. Under

[9] This alternative proposes that the Secretary may implement additional measures to protect critical infrastructure at Glen Canyon Dam including further reductions to releases from Lake Powell and additional use of the CRSP Upper Initial Units. The possible outcomes of such measures are unknown; therefore, for modeling purposes it was assumed that Glen Canyon Dam would continue to attempt to release a minimum of 7.0 maf unless constrained by infrastructure. The Secretary would ensure appropriate consultation with Basin entities would occur consistent with the Law of the River.

Equalization, Lake Powell would release a minimum of 9.5 maf and may release more to balance storage with Lake Mead (see **Appendix A**, CRSS Model Documentation, for details).

S.2.2.3. Infrastructure Protection and Other Considerations

If Lake Powell is projected to fall below 3,490 feet after additional releases are made from CRSP Upper Initial Units (refer to **Section S.2.4**), Reclamation would consider adjusting operations in consultation with the Basin States to protect critical infrastructure.

S.2.3 Storage and Delivery of Conserved System and Non-System Water

S.2.3.1. Lake Powell and Lake Mead Mechanisms

There would be no new mechanisms to conserve and store water in Lake Powell or Lake Mead since agreements among Basin water users would be required.

S.2.3.2. Treatment of Pre-2027 ICS

ICS created under the 2007 Interim Guidelines and 2019 Drought Contingency Plan (DCP) that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. Modeling assumptions for the timing of these deliveries can be found in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery.

S.2.4 Additional Activities Above Lake Powell

S.2.4.1. Upper Basin Conservation

No Upper Basin conservation would be included since it would require agreements outside of Reclamation's control.

S.2.4.2. Releases to Protect Glen Canyon Dam

If Lake Powell's physical elevation is projected to go below 3,525 feet, CRSP Upper Initial Units would increase their releases within their RODs to increase elevations at Lake Powell contingent on hydrologic conditions. Reclamation would identify triggers for when additional Upper Basin actions would be required to protect critical infrastructure. Any volumes released for the protection of Glen Canyon Dam would begin to be recovered when Lake Powell is no longer projected to go below 3,525 feet by assuming that the Upper Initial Units return to their normal annual operating targets. The frequency and volumes of the assumed releases to protect Glen Canyon Dam are assessed in **Appendix O**, Analysis of Powell Infrastructure Protection Releases.

S.3 Enhanced Coordination Alternative

The Enhanced Coordination Alternative is based on proposals and concepts from specific Basin Tribes, federal agencies (U.S. Fish and Wildlife Service, National Park Service, and representing principles put forth by the Western Area Power Administration), and other stakeholders. This alternative seeks to protect critical infrastructure while benefitting key resources (such as environmental, hydropower, and recreation) through an approach to distributing storage between Lake Powell and Lake Mead that

enhances the reservoirs' abilities to support the Basin. It applies a pro rata[10] Lower Basin shortage distribution to evaluate the potential impacts of distributing reductions among all mainstream lower Colorado River water users in Arizona, Nevada, and California.

S.3.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

S.3.1.1. Shortage Conditions

Shortage volumes up to 3.0 maf would be determined for the upcoming CY based on the October 1 sum of effective[11] storage in Lake Powell and physical storage in Lake Mead and be distributed pro rata among Lower Basin water users independent of state (see **Table S-3**). Required shortages could be partially or fully offset by delivering or converting previously conserved water, subject to provisions described in **Section S.3.3**. The shortage guidelines are summarized below and shown in **Figure S-5**.

- When the sum of Lake Powell effective storage and Lake Mead physical storage is equal to or less than 60 percent of combined capacity and greater than or equal to 30 percent combined capacity, a shortage volume would be imposed for that year based on a function of storage, with 1.3 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 30 percent of capacity.
- When the sum of Lake Powell effective storage and Lake Mead physical storage is less than 30 percent of combined capacity, a shortage volume of 3.0 maf would be imposed for that year.

Table S-3
Shortage Distribution,
Enhanced Coordination Alternative

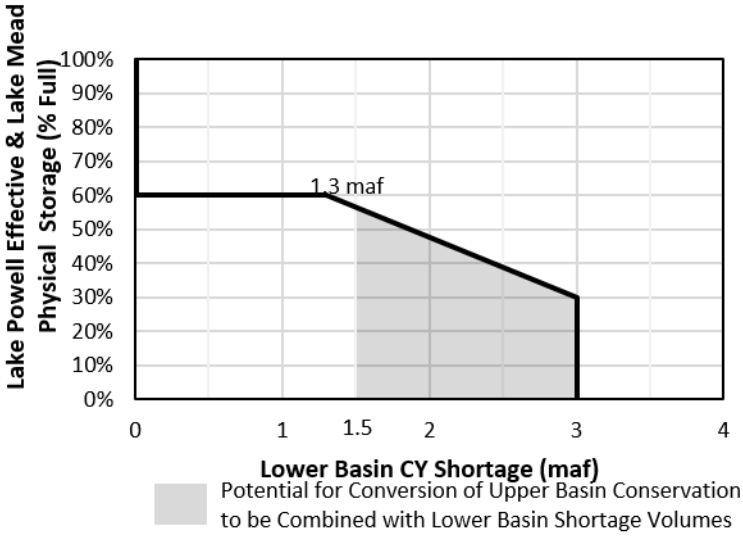
Entity	Percentage of Total Shortages
Arizona	31.11
California	48.89
Nevada	3.33
Mexico	16.67
Total	**100**

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[10] Additional agreements and other legal authorities would be needed to implement any pro rata operations that are inconsistent with the Decree. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, for additional information on considerations related to use of pro rata shortage distributions in alternatives.

[11] "Effective" elevation or storage is calculated as physical elevation (storage) minus any conserved volume that is held in the respective reservoir.

Figure S-5
Shortage Guidelines to Reduce Deliveries from Lake Mead, Enhanced Coordination Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The pro rata distribution would occur outside the priority system. Shortages would be distributed on a proportional basis (i.e., at the same percentage reduction from each user's entitlement) across all Lower Basin water users, including Mexico (see **Appendix C**, Shortage Allocation Model [SAM] and Alternative Distribution Model [ADM] Documentation, for additional detail on assumptions for this distribution method).

S.3.1.2. Surplus Conditions

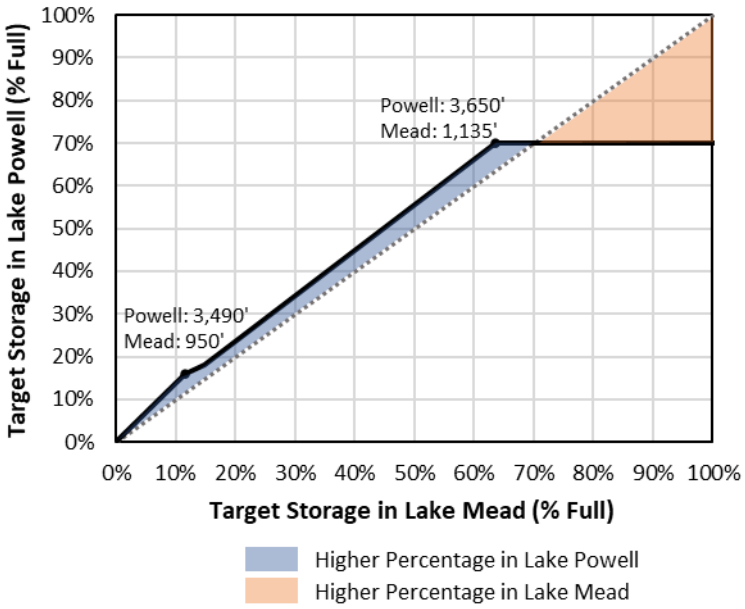
Volumes above normal apportionment would be distributed only when criteria are met in Lake Mead for a 70R Surplus Condition or a Flood Control Surplus Condition, see footnotes 3 and 4 for details.

S.3.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

Operations would target a specific distribution of storage across Lake Powell and Lake Mead for any given total volume of water. The curve in **Figure S-6**, called the "target storage distribution curve," depicts the target storage in Lake Powell versus the target storage in Lake Mead. The dotted diagonal line marks a 50/50 split for reference, and the target storage curve is variable across that line, indicating the portion where Lake Powell is at higher percent capacity than Lake Mead (emphasized with blue shading) and the portion where Lake Mead is at higher percent capacity than Lake Powell (emphasized with orange shading). From 0 percent to 63 percent combined storage (the total combined percent full when Lake Powell is at elevation 3,650 feet and Lake Mead is at

elevation 1,135 feet), operations would target keeping more water in Lake Powell. Above 63 percent full, a greater portion of water would be proactively sent to Lake Mead to prevent unplanned spill-avoidance releases and protect Glen Canyon Dam at high elevations.

Figure S-6
Coordinated Operations of Lake Powell and Lake Mead, Enhanced Coordination Alternative



S.3.2.1. Primary Operations

Each year, an initial WY release volume from Lake Powell would be calculated on October 1 using four factors:

1. October 1 physical[12] storage in Lake Powell and Lake Mead
2. Target storage distribution curve in **Figure S-6**
3. Preceding 10-year running average inflow to Lake Powell
4. Lower Basin delivery reductions for the upcoming CY

If the relative storage in Lake Powell and Lake Mead was exactly at the target distribution per the curve, Lake Powell's release would be equal to its 10-year running average inflow minus the volume of Lower Basin shortage for the upcoming CY. Since it is unlikely that the previous year exactly achieved the target storage distribution due to hydrologic uncertainty, a volume equal to the discrepancy, which could be positive (too much water was held in Lake Powell) or negative (too much was released to Lake Mead) would be factored into the upcoming WY release to align storage with the previous year's intended target. The maximum release each month is 900.0 kaf to prevent

[12] Using physical storage instead of effective storage for Lake Powell releases would prevent conservation from affecting the intended target storage distribution.

large monthly release volumes from causing sand evacuation below Glen Canyon Dam, which can potentially lead to negative impacts on multiple resources in the Grand Canyon. Therefore, the maximum WY release is 10.8 maf to avoid releasing volumes that could cause sediment scouring below Glen Canyon Dam.[13] The minimum WY release is 4.7 maf, which is the volume that still maintains minimum Long-Term Experimental and Management Plan releases.

In the spring, a one-time adjustment would be made to the remaining WY initial release volume if the end-of-water-year forecast shows that the end-of-water-year Lake Powell storage is off target by more than 1.0 maf. This would provide an opportunity to avoid a very large or very small WY release in the subsequent year. If an adjustment is warranted, the volume increase or decrease would be distributed among the remaining 6 months while ensuring that the adjustment would not cause the monthly release to be greater than 900.0 kaf, or less than Long-Term Experimental and Management Plan minimum flows.

S.3.2.2. Coordination at High Elevations

This alternative is based on a target distribution of storage between Lake Powell and Lake Mead throughout the range of combined storage volumes and does not have specific coordinated operations at high elevations.

S.3.2.3. Infrastructure Protection and Other Considerations

As combined Lake Powell and Lake Mead storage fall, planned WY releases from Lake Powell decline to help protect critical infrastructure at Glen Canyon Dam. No actions to protect critical infrastructure beyond the conservative target storage distribution curve and additional releases from CRSP Upper Initial Units (refer to **Section S.3.4**) are included in this alternative.

Annual releases above 10.8 maf would be made if required to avoid spills and protect Glen Canyon Dam at high elevations.

At Reclamation's discretion and in coordination with appropriate Basin entities, additional adjustments to Lake Powell WY release volumes could be made to mitigate potential negative impacts on resources between Glen Canyon Dam and Hoover Dam. These adjustments would be reconciled in the subsequent year through the end-of-water-year target storage adjustment.

S.3.3 Storage and Delivery of Conserved System and Non-System Water

This alternative incorporates specific elements that are designed to provide enhanced flexibility and predictability for water users via a storage and conversion mechanism in Lake Powell and storage and delivery mechanisms in Lake Mead. The storage, conversion and delivery mechanisms include assumptions for contributions of both consumptively used and unused tribal water, which may require additional authorities and represents the concept of enabling Basin Tribes to realize additional benefits from quantified water rights (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water and **Appendix H**, Sensitivity

[13] While sediment scour is often driven by short-duration, high-flow events (i.e., instantaneous flow rates), not by steady-state or annual volumes, incorporating monthly release limits into this alternative helps to ensure that operationally mandated high WY and monthly release volumes do not negatively impact sediment.

Analysis – Effects of Demand Schedule Assumptions on Modeled Unused Tribal Water Available for Storage in the Enhanced Coordination Alternative).

Three pools capture a range of opportunities to store, convert and deliver water for the benefit of water users and the system: the Lake Powell mechanism, the water user-controlled Lake Mead mechanism, and the Lake Mead Protection Pool, which was informed by a group of Basin Tribes and would be controlled by Reclamation for Lower Basin-wide benefits. The design of these mechanisms supports proactive conservation and water user flexibility while the relatively lower accumulation limits represent a goal of ensuring that system storage is not overtaken by user-controlled conservation.

S.3.3.1. Lake Powell Mechanism

Water conserved by Upper Basin users would be stored in a pool in Lake Powell that can reach a maximum volume of 2.0 maf. Water in this conservation pool would be included for purposes of determining Lake Powell releases but excluded from determinations of shortage volumes until it is converted to system water. Upper Division States and Upper Basin Tribes would have equal access to contribute to the conservation pool and to use their conserved water in intra- and interstate transactions with other Upper Basin users. Upper Basin Tribes would receive credit for the contribution of both conserved consumptive use and unused water to the pool. Assumptions related to contributions to the Lake Powell conservation pool are described in **Section S.3.4.1**.

Water held in the Lake Powell conservation pool would be converted to system water and combined with Lower Basin shortages to provide system benefits based on the shortage curve in **Figure S-5**. When Lower Basin CY shortages are greater than 1.5 maf, a volume equal to one-third of the volume above 1.5 maf would be converted from the Lake Powell pool into system water such that the total of Lower Basin shortages and conversion of Upper Basin water equal the required total shortage volume (i.e., above 1.5 maf, there is a two-to-one Lower Basin shortage-to-Upper Basin conversion ratio). If the prescribed two-to-one volume is not available in the Lake Powell conservation pool, 100 percent of the available volume would be converted, and the Lower Basin would take the balance of shortages.

S.3.3.2. Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 5.0 maf, which includes the storage of pre-2027 ICS. Annual total and state-based limits for conservation volumes and delivery of conserved water are presented in **Table S-4**. All conserved water stored in Lake Mead would be included in determinations of Lake Powell releases and shortage volumes. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users.

Table S-4
Volume Limitations of Storage and Delivery of Conserved Water, Enhanced Coordination Alternative

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery (kaf)
Arizona	466.67	700	620
California	733.333	1,900	980
Nevada	50	700	70
Mexico	250	1,700	330*
Total	**1,500**	**5,000**	**2,000**

*According to the modeling assumption for Mexico, water stored in the bank may only be used to mitigate Mexico's reductions exceeding 250.0 kaf. This activity is considered a "delivery" (i.e., conversion) from the bank. As a result, banking activity will not cause Mexico's delivery to exceed 1.7 maf. The 1944 Water Treaty authorizes scheduled delivery of up to 200.0 kaf in excess of the 1.5 annual allotment to Mexico.
Note: Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Water users could contribute and convert or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool. At the time the water is conserved, a one-time, seven-percent assessment would be deducted from the conserved volume and added to the Protection Pool. Conserved water could be used to offset up to 1.5 maf of required shortages. Conversion and delivery of conserved water would not be allowed when Lake Mead's physical elevation is below 1,025 feet.

S.3.3.3. Lake Mead Mechanism (Protection Pool)

The Protection Pool would be a pool of water controlled by Reclamation that can reach a maximum volume of 2.0 maf. It would acquire water through multiple mechanisms, including but not limited to system assessments on water user-created conservation, potentially compensated Lower Basin tribal water (conserved consumptive use and unused), system efficiency projects and potentially compensated nontribal conservation. Contents of the Protection Pool would be included in determinations of Lake Powell releases and shortage volumes.

The Protection Pool could be used for a range of purposes, including, but not limited to, meeting federal firming obligations,[14] other federal delivery obligations, protecting Lower Basin water supplies, protecting infrastructure, and providing environmental benefits. Modeling assumptions related to logic for creation and use of Protection Pool volumes can be found in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water. There are no annual creation or delivery constraints.

[14] The Secretary is obligated to firm certain volumes of CAP non-Indian agricultural water provided as part of Indian water rights settlements to specific tribes in Arizona, including under Section 105(a) of the Arizona Water Settlements Act of 2004, Pub. L. 108-451, 118 Stat. 3478.

The Protection Pool was designed with significant input from representatives of Basin Tribes. The elements are modeled within the Enhanced Coordination Alternative, but the intention is to allow for their implementation within any operational framework that includes a storage and delivery mechanism (including frameworks where conservation is excluded from all release and shortage determinations).

S.3.3.4. Treatment of Pre-2027 ICS

ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be transferred to the Post-2026 Lake Mead water user-controlled mechanism immediately and would be subject to all provisions described in the previous section.

S.3.4 Additional Activities Above Lake Powell

S.3.4.1. Upper Basin Conservation

Exact volumes of Upper Basin conservation over time are uncertain, but for the purposes of modeling, volumes up to a maximum volume per year may be added depending on hydrologic conditions. The maximum phases in over time: from 2027 to 2031, the maximum is 200.0 kaf; from 2032-2036, the maximum is 275.0 kaf; after 2036, the maximum is 350.0 kaf. Conservation is modeled as a single lumped volume; no assumptions are made with respect to contributions from different entities or via specific activities. Assumptions related to the storage of unused Upper Basin tribal water are included in these volumes.

S.3.4.2. Releases to Protect Glen Canyon Dam

The coordinated operations included in this alternative, due to their storage distribution approach and lower releases at Lake Powell (down to 4.7 maf) are very effective at protecting critical infrastructure at Glen Canyon Dam. Therefore, while specific assumptions for releases from CRSP Upper Initial Units have not been developed for this alternative, Reclamation maintains the authority to operate its reservoirs to protect Glen Canyon Dam infrastructure.

S.4 Maximum Operational Flexibility Alternative

The Maximum Operational Flexibility Alternative is informed by a proposal submitted by a consortium of conservation organizations. This alternative incorporates proactive responses, targeted reservoir management strategies, and innovative and flexible tools to address an increasingly variable set of future hydrologic conditions. The operations are designed to help stabilize system storage, incentivize proactive water conservation, and extend the benefits of conservation and operational flexibility to a wide range of resources.

This alternative is based on "dual indicator" operations for determining annual releases from Lake Powell and Lake Mead: system storage and recent hydrology[15] are used in combination to determine

[15] The submission by the conservation organizations proposes the use of a Climate Response Indicator as part of the "dual indicator" approach. For modeling purposes, this concept has been translated into the previous 3-year average Lees Ferry natural flow.

operations. Additionally, it introduces the Conservation Reserve as a flexible tool for water conservation and management.

S.4.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

S.4.1.1. Shortage Conditions

Shortage volumes up to 4.0 maf would be determined for the upcoming CY based on October 1 total system[16] effective storage and the previous 3-year average natural flow at Lees Ferry, Arizona. Shortages would be distributed based on priority as described in Approach 1 of the Supply Driven Alternative (refer to **Section S.5.1**). Required shortages could be partially or fully offset by delivering or converting previously conserved water, subject to provisions described in **Section S.4.2.2**. The shortage guidelines and relevant conditions are summarized below and shown in **Figure S-7** and **Table S-5**.

- When total system effective storage is at or below 80 percent of capacity and at or above 60 percent of capacity, a shortage volume would be imposed for that year based on a function of storage, with 0.0 maf of shortage at 80 percent of capacity increasing linearly to 1.0 maf at 60 percent of capacity.
- When total system effective storage is below 60 percent of capacity and at or above 50 percent of capacity, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.5 maf at 50 percent of capacity (S1 curve in **Figure S-7**).
    - If the previous 3-year average Lees Ferry natural flow is less than 14.0 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.75 maf at 50 percent of capacity (S2 curve in **Figure S-7**).
    - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.0 maf at 50 percent of capacity (S3 curve in **Figure S-7**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.25 maf at 50 percent of capacity (S4 curve in **Figure S-7**).
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 50 percent of capacity (S5 curve in **Figure S-7**).

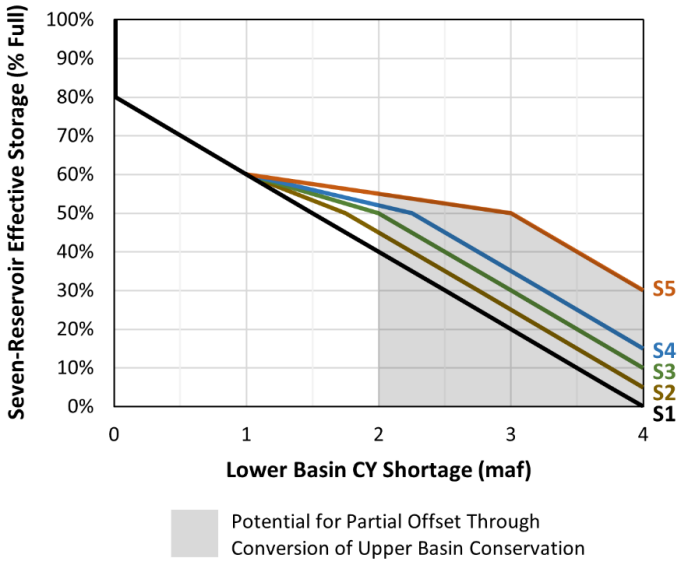
[16] Flaming Gorge, Blue Mesa, Navajo, Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu Reservoirs.

- When total system effective storage is 50 percent of capacity or less, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
  - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.5 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 0 percent of capacity (S1 curve in **Figure S-7**).
  - If the previous 3-year average Lees Ferry natural flow is less than 14.0 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.75 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 5 percent of capacity (S2 curve in **Figure S-7**). Below 5 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
  - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 10 percent of capacity (S3 curve in **Figure S-7**). Below 10 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
  - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.25 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 15 percent of capacity (S4 curve in **Figure S-7**). Below 15 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
  - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 3.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 30 percent of capacity (S5 curve in **Figure S-7**). Below 30 percent of capacity, a shortage of 4.0 maf would be imposed for that year.

Table S-5
Shortage Curves and Relevant Conditions,
Maximum Operational Flexibility Alternative

Shortage Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Shortage Increase Compared to S1 Curve at 50% Full (kaf)
S1	≥ 14	N/A
S2	< 14 to ≥ 12	250
S3	< 12 to ≥ 10	500
S4	< 10 to ≥ 8	750
S5	< 8	1,500

Figure S-7
Shortage Guidelines to Reduce Deliveries from Lake Mead, Maximum Operational Flexibility Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

S.4.1.2. Surplus Conditions

Volumes above normal apportionment would be distributed only when criteria are met in Lake Mead for a Flood Control Surplus Condition, see footnotes 3 and 4 for details.

S.4.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

The WY release from Lake Powell would be determined based on the combined effective storage of CRSP reservoirs (Lake Powell, Flaming Gorge, Blue Mesa, and Navajo) on October 1 and the previous 3-year average natural flow at Lees Ferry, Arizona. The operational zones and relevant conditions are summarized below and shown in **Figure S-8** and **Table S-6**.

Figure S-8
Coordinated Operations of Lake Powell and Lake Mead,
Maximum Operational Flexibility Alternative

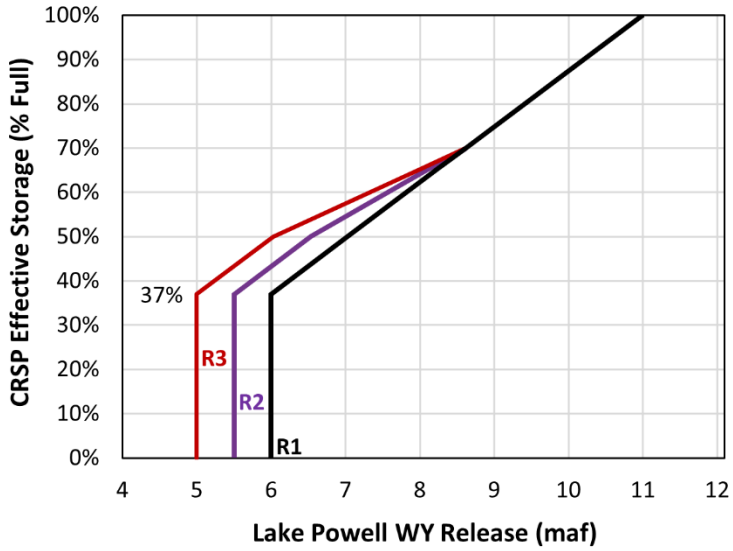


Table S-6
Release Curves and Relevant Conditions,
Maximum Operational Flexibility Alternative

Lake Powell Release Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Release Decrease Compared to R1 Curve at 50% Full (kaf)
R1	≥ 10	N/A
R2	< 10 to ≥ 8	500
R3	< 8	1,000

S.4.2.1. Primary Operations

- When CRSP effective storage is at or below 100 percent of capacity and at or above 70 percent of capacity, a release volume would be determined for that year based on a function of storage, with 11.0 maf release at 100 percent of capacity decreasing linearly to 8.6 maf at 70 percent of capacity.
- When CRSP effective storage is at or below 70 percent of capacity and at or above 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 7.0 maf at 50 percent of capacity (R1 curve in **Figure S-8**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a

function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.5 maf at 50 percent of capacity (R2 curve in **Figure S-8**).

- If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.0 maf at 50 percent of capacity (R3 curve in **Figure S-8**).

- When CRSP effective storage is at or below 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow:
  - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 7.0 maf at 50 percent of capacity decreasing linearly to 6.0 maf at 37 percent of capacity (R1 curve in **Figure S-8**). Below 37 percent of capacity, the determined release would be 6.0 maf.
  - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.5 maf at 50 percent of capacity decreasing linearly to 5.5 maf at 37 percent of capacity (R2 curve in **Figure S-8**). Below 37 percent of capacity, the determined release would be 5.5 maf.
  - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.0 maf at 50 percent of capacity decreasing linearly to 5.0 maf at 37 percent of capacity (R3 curve in **Figure S-8**). Below 37 percent of capacity, the determined release would be 5.0 maf.

S.4.2.2. Coordination at High Elevations

This alternative uses the Conservation Reserve pool to coordinate Lake Powell and Lake Mead throughout the range of elevations and does not have specific coordinated operations at high elevations.

S.4.2.3. Infrastructure Protection and Other Considerations

When physical elevation at Lake Powell is below 3,510 feet, Lake Powell monthly releases would be equal to the minimum of either monthly inflow minus losses or the monthly volume corresponding to the WY release determined by the curve. The minimum monthly release would be based on 5,000 cubic feet per second (cfs) unless it is reduced by Glen Canyon Dam infrastructure constraints below physical elevation 3,490 feet.

Lake Powell WY releases could be adjusted based on flexibilities provided by the Conservation Reserve as described in **Section S.4.3**.

S.4.3 Storage and Delivery of Conserved System and Non-System Water

S.4.3.1. Combined Lake Powell and Lake Mead Mechanism

The Conservation Reserve is a pool that would store water conserved by Colorado River water users in either basin (including Mexico) and would be distributed strategically across Lake Powell and Lake

Mead to protect infrastructure and benefit a range of resources including the Colorado River Delta, Lower Colorado River Multi-Species Conservation Plan, and Grand Canyon. Except when Lake Powell or Lake Mead is near a critically high or low elevation, water in the Conservation Reserve would be excluded from determining basic (curve-based) WY releases from Lake Powell and shortage volumes until it is converted to system water. The timing and volume criteria for this conversion are described below.

The maximum volume of the Conservation Reserve would be 8.0 maf, with 3.0 maf of space allocated to Upper Basin users and 5.0 maf allocated to Lower Basin users, which includes the storage of pre-2027 ICS. There would be no maximum total storage for any single user or state, though there would be total annual creation and delivery limits as shown in **Table S-7**. At the time the water is conserved, a one-time 10-percent assessment would be deducted from the conserved volume and added to system water. Transactions, including interstate transactions, could occur between users within the basin of origin.

Table S-7
Annual Total Conservation Creation and Delivery or Conversion Limits by Basin

Basin	Maximum Annual Contribution Limits (kaf)	Maximum Annual Delivery or Conversion Limits (kaf)
Upper	500	Conversion volume required to bring Lower Basin shortage to 2.0 maf
Lower	3,000 minus shortage (total of shortage and creation cannot exceed 3,000)	3,000

Note: Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Reclamation would determine how to allocate the Conservation Reserve volume between reservoirs and could increase or decrease Lake Powell's basic WY release volume to meet infrastructure needs or resource goals. Operation of the Conservation Reserve would not affect tracking of Lee Ferry flows.

Upper Basin users' conserved water would be converted to system water based on the shortage curve in **Figure S-8**. When Lower Basin shortages are greater than 2.0 maf, the volume above 2.0 maf would be converted from Upper Basin users' Conservation Reserve water to system water, subject to availability in the Reserve. The required Lower Basin shortage volume would be reduced by whatever volume of previously conserved Upper Basin water is converted.

Lower Basin water users could conserve and request delivery of stored water in their accounts at their discretion to offset up to the full required shortage amount, subject to annual creation and delivery limits and constrained by the priority of using Conservation Reserve water to keep Lake Powell above 3,510 feet and Lake Mead above 1,000 feet.

S.4.3.2. Treatment of Pre-2027 ICS

ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be transferred to the Conservation Reserve in 2027 and would be subject to all provisions described in the previous section.

S.4.4 Additional Activities Above Lake Powell

S.4.4.1. Upper Basin Conservation

Exact volumes of Upper Basin conservation over time are uncertain, but for the purposes of modeling, volumes up to 500.0 kaf per year may be added depending on hydrologic conditions. The framework targets an average conservation volume of 200.0 kaf per year. Conservation is modeled as a single lumped volume; no assumptions are made with respect to contributions from different entities or via specific activities.

S.4.4.2. Releases to Protect Glen Canyon Dam

Based on the proposal submitted by the conservation organizations on which this alternative is based, this alternative does not include adjustments to the releases of the CRSP Upper Initial Units to protect infrastructure at Glen Canyon Dam. However, Reclamation maintains the authority to operate these reservoirs to protect Glen Canyon Dam infrastructure.

S.5 Supply Driven Alternative

The Supply Driven Alternative provides a Lake Powell operation based solely on historical natural flow. It also incorporates concepts from the separate proposals submitted by the Upper Division and Lower Division States, as well as ideas emerging from discussions with the Basin States during spring 2025. In this alternative, annual Lake Powell releases would be determined based on a set percentage of the preceding 3-year average natural flow at Lees Ferry, and Lower Basin deliveries would be determined based on Lake Mead elevation.

S.5.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

S.5.1.1. Shortage Conditions

Shortage volumes up to 2.1 maf would be determined for the upcoming CY based on August 1 Lake Mead effective elevation. To analyze a wide range of potential impacts, at the request of the Lower Division States, this alternative considers two different approaches to the distribution of shortages among mainstream Lower Colorado River users:

1. Lower Basin Priority (LB Priority): up to 1.5 maf, intra-state priority using state distributions submitted by Lower Division States; above 1.5 maf, priority using a state distribution based on the interpretation of priority as described in the No Action Alternative (**Section S.1.1.1**).

2. Lower Basin Pro Rata (LB Pro Rata): up to 1.5 maf, intra-state pro rata using state distributions submitted by Lower Division States; above 1.5 maf, intra-state pro rata distributed to states proportionally based on unreduced apportionments.

Table S-8 reports how shortage volumes would be divided among the states and Mexico for each approach up to 1.5 maf. **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, includes the results of additional modeling to understand how excluding tribes from shortages in both distribution schemes would impact water deliveries.

Table S-8
Lower Division State-Submitted Shortage Distributions

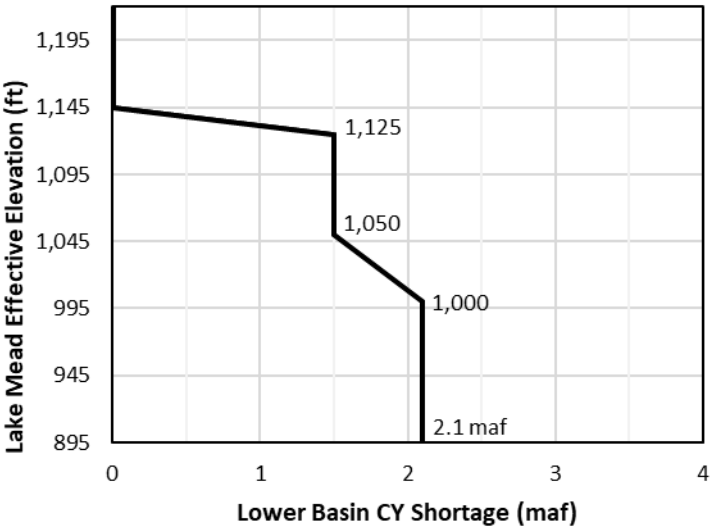
Entity	Shortage (%) from 0 to 300 kaf	Shortage (%) from 300 to 1,500 kaf	Total Shortage (kaf) when Lower Basin-wide Shortage is 1,500 kaf	Shortage (%) 1,500 kaf to 2,100 kaf	
	LB Priority and LB Pro Rata	LB Priority and LB Pro Rata	LB Priority and LB Pro Rata	LB Priority	LB Pro Rata
Arizona	80.00	43.33	760	76.26	27.20
California	0	36.67	440	0	52.80
Nevada	3.33	3.33	50	7.08	3.33
Mexico	16.67	16.67	250	16.67	16.67

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Required shortages could be partially or fully offset by delivering or converting previously conserved water, subject to provisions described in **Section S.5.3**. The shortage guidelines are summarized below and shown in **Figure S-9**.

- When Lake Mead effective elevation is at or below 1,145 feet and at or above 1,125 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,145 feet increasing linearly to 1.5 maf at 1,125 feet.
- When Lake Mead effective elevation is at or below 1,125 feet and at or above 1,050 feet, a shortage volume of 1.5 maf would be imposed for that year.
- When Lake Mead effective elevation is at or below 1,050 feet and at or above 1,000 feet, a shortage volume would be imposed for that year based on a function of elevation, with 1.5 maf of shortage at 1,050 feet increasing linearly to 2.1 maf at 1,000 feet.
- When Lake Mead effective elevation is below 1,000 feet a shortage volume of 2.1 maf would be imposed for that year.

Figure S-9
Shortage Guidelines to Reduce Deliveries from Lake Mead, Supply Driven Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

S.5.1.2. Surplus Conditions

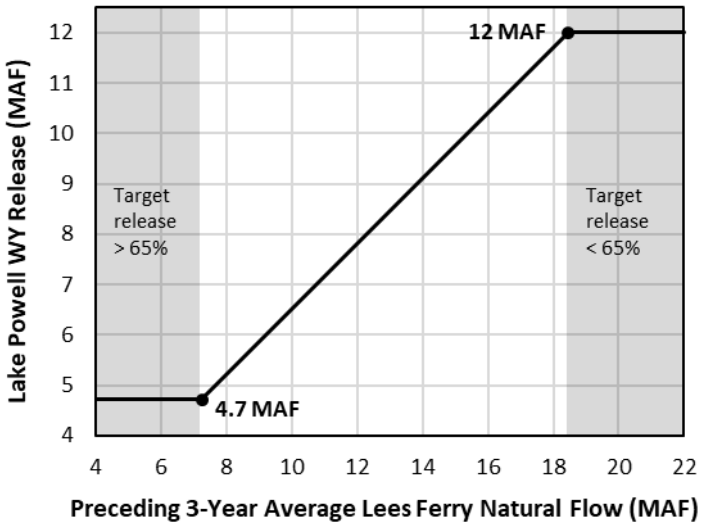
This alternative incorporates three categories of surplus: Flood Control and 70R, which are described in **Section S.1.1.2**, and Domestic Surplus. A Domestic Surplus would be determined anytime the August 1 Lake Mead effective elevation is at or above 1,165 feet and Flood Control or 70R Surplus is not triggered. Up to 500.0 kaf of surplus volumes would be distributed.

S.5.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

S.5.2.1. Primary Operations

Lake Powell WY release volumes would be determined on October 1 as a fixed percentage (65 percent) of the preceding 3-year average natural flow at Lees Ferry, Arizona (see **Figure S-10**). **Appendix D**, Sensitivity Analysis – Effects of Natural Flow Percentage Used for the Supply Driven Alternative, explores the implications of using different natural flow percentages. Other than considerations related to critical high or low elevations, WY releases would be constrained to between 4.7 and 12.0 maf regardless of the volume determined by the natural flow-based calculation.

Figure S-10
Coordinated Operations of Lake Powell and Lake Mead, Supply Driven Alternative



S.5.2.2. Coordination at High Elevations

This alternative does not coordinate operations at high elevations.

S.5.2.3. Infrastructure Protection and Other Considerations

This alternative assumes that no adjustments to Lake Powell releases would be made to protect physical elevation 3,490 feet; however, Reclamation maintains the authority to modify operations to protect Glen Canyon Dam infrastructure.

S.5.3 Storage and Delivery of Conserved System and Non-System Water

S.5.3.1. Lake Powell Mechanism

Water conserved by Upper Basin users would be stored in a pool in Lake Powell that could reach a maximum volume of 3.0 maf. Upper Division States' water and Upper Basin Tribes' water would be able to contribute to the conservation pool and to use their conserved water in intra- and interstate transactions with other Upper Basin users. Water in the Lake Powell conservation pool can be released if needed to meet the determined WY volume.

S.5.3.2. Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in a pool in Lake Mead that could reach a maximum volume of 8.0 maf, which includes the storage of pre-2027 ICS. Annual total and state-based limits for conservation volumes and delivery of conserved water are presented in **Table S-9**, but each state can choose to share its dedicated space. All water stored in the Lake Mead conservation pool would be excluded from determinations of shortage volumes until it is converted to system water by a user to offset their required shortages. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements,

would be able to contribute to the Lake Mead conservation pool and to use their conserved water in intra- and interstate transactions with other Lower Basin users.

Water users could contribute and convert or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool. In the year the water is conserved, a 5-percent assessment would be deducted from the conserved volume and added to system water. In every subsequent year, 3 percent of the stored volume would be deducted and converted to system water. Delivery of conserved water would not be allowed when Lake Mead's physical elevation is below 1,025 feet.

Table S-9
Supply Driven Alternative Volume Limitations of Storage of Conserved Water

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Conversion or Delivery (kaf)
Arizona	880	3,000	465
California	880	3,000	745
Nevada	225	1,000	90
Mexico	500	1,000	100
Total	**2,485**	**8,000**	**1,400**

Note: Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

S.5.3.3. Treatment of Pre-2027 ICS Conservation

ICS created under the 2007 Interim Guidelines and 2019 DCP that remains in Lake Mead in 2027 would be used or converted to the Post-2026 Lake Mead mechanism using a phased approach over 10 years. Once transferred to the new mechanism, it would be subject to all provisions described in the previous section.

S.5.4 Additional Activities Above Lake Powell

S.5.4.1. Upper Basin Conservation

Exact volumes of Upper Basin conservation over time are uncertain, but for the purposes of modeling, conservation up to 200.0 kaf per year is included, with variable annual volumes based on hydrologic conditions as described in the Enhanced Coordination Alternative. Conservation is modeled as a single lumped volume; no assumptions are made with respect to contributions from different entities or via specific activities. Additional hydrology-dependent volumes may be added to the Lake Powell pool based on annual unused Upper Basin tribal water.

S.5.4.2. Releases to Protect Glen Canyon Dam

If Lake Powell's elevation falls below 3,525 feet CRSP Upper Initial Units would increase their releases within their RODs to increase elevations at Lake Powell, up to 500.0 kaf per year

contingent on hydrologic conditions. Any volumes released for the protection of Glen Canyon Dam would begin to be recovered when Lake Powell is above 3,535 feet by assuming that the Upper Initial Units return to their normal annual operating targets. The frequency and volumes of the assumed releases to protect Glen Canyon Dam are assessed in **Appendix O**, Analysis of Powell Infrastructure Protection Releases.

S.5.4.3. Additional Modeling Assumptions

In years when Lake Powell cannot meet its required WY release because of low elevation infrastructure constraints, additional water is introduced into the system to (partially) make up the shortfall. For modeling purposes, this supplemental volume is termed "gap water" and is modeled both to provide an estimate of the supplemental volume of water needed in the Upper Basin to ensure the required WY release can be made from Lake Powell and associated downstream impacts of meeting the required WY release. This supplemental water is injected into Lake Powell and released when conditions allow, subject to the same low-elevation release constraints. Any portion not released in a given WY is tracked as carryover and released in subsequent years. The annual amount of gap water is limited to no more than 23 percent[17] of the Upper Basin's modeled depletion for that year, minus any Upper Basin conservation Additional detail is provided in **Appendix A**, CRSS Model Documentation.

S.6 Alternatives Considered but Eliminated from Detailed Analysis

Reclamation received a number of submissions representing commenters' proposed operations of Colorado River reservoirs. Some submissions presented sufficient detail to potentially be considered as an action alternative, while others offered operational concepts or components of an alternative. In either case, the following "alternatives" were brought forward during internal and public scoping. These alternatives were considered but eliminated from detailed analysis because they (1) would not fully meet the purpose and need of the Post-2026 action; (2) are infeasible or inconsistent with the policy objectives for Colorado River operations, including consistency with applicable federal law;[18] or (3) are addressed or encompassed by the range of alternatives analyzed.

S.6.1 Boating Alternative – Maintaining Lake Powell Levels for Recreation

Comments related to boating alternatives focused on maintaining water levels at Lake Powell (and Lake Mead) to serve recreational boating needs. Many commenters wrote in support of the BlueRibbon Coalition's "Path to 3588' Plan," which proposes to maintain Lake Powell at an elevation of 3,588 feet. One commenter proposed maintaining Lake Powell at 3,600 feet, and three commenters proposed filling Lake Powell to full pool. Other commenters suggested maintaining Lake Powell at an elevation of 3,588 feet to allow the Castle Rock Cut to be navigable. Additionally,

[17] The 23-percent limit is based on the ratio of the maximum Lower Basin shortage (2.1 maf) to the total Lower Basin apportionment to the U.S. and Mexico (9.0 maf).

[18] Inclusive of existing legal authorities and contractual obligations. This would not preclude the reasonably foreseeable acquisition of certain new or modified legal authorities necessary to implement new interim guidelines. However, new legal authorities that would result in impracticalities or are unlikely to be widely acceptable among stakeholders are too speculative to include in this Final EIS.

some commenters asked that Reclamation reconsider how release rates are determined—one noted potential effects on the trout fishery below Glen Canyon Dam, while another recommended evaluating minimum flows of 8,000 cfs from April 1 through September 22 to preserve safe whitewater boating below the dam.

This alternative was not carried forward because a recreation-focused target elevation does not fully meet the purpose and need of the Post-2026 action. Focusing solely on boating would risk noncompliance with water delivery obligations and operational requirements, which would be inconsistent with Reclamation's policy objectives. However, maintenance of higher Lake Powell elevations, as feasible, is integrated into the range of alternatives, primarily the Enhanced Coordination and Maximum Operational Flexibility Alternatives. These operations were designed in recognition of their potential to benefit multiple resources and uses, including recreation. With respect to minimum flows below Glen Canyon Dam, targeting specific releases from Lake Powell at the sub-annual level is outside the scope of this National Environmental Policy Act effort, which is focused on annual releases.

S.6.2 Ecosystem Alternative

Comments regarding an ecosystem alternative called for Reclamation to prioritize the ecosystem health of the Colorado River by protecting key components such as wildlife, vegetation, habitats, tributary ecosystems, and wetlands. Specific wildlife habitats mentioned included the Grand Canyon, the Lower Colorado River, the Salton Sea, and the Colorado River Delta. Several commenters emphasized that consumptive water use from agriculture, lawns, and golf courses be decreased to protect these habitats. In addition, one commenter suggested that Reclamation analyze and implement releases of cold water with high dissolved oxygen from Glen Canyon Dam to protect the threatened humpback chub, noting that low water levels at Lake Mead creating the Pearce Ferry rapid may serve as an effective management strategy for protecting native and listed fish species. Another commenter urged the development of a "Protect Grand Canyon Alternative" to "ensure high-flow experiments, safe and navigable flows, a healthy ecosystem including protecting the sediment resource and our native fish and preserving precious cultural resources in this sacred landscape."

Critical ecosystem needs were considered in the development of every action alternative, including alternatives such as the Enhanced Coordination and Maximum Operational Flexibility Alternatives, which incorporate protection as part of coordinated reservoir operations. However, this Ecosystem Alternative was not advanced because it would prioritize ecosystem protection over the operational and legal requirements associated with Colorado River water deliveries and management. While several action alternatives include conservation measures, operational flexibility, and actions intended to benefit ecosystem resources, those alternatives were developed to balance ecosystem considerations with the primary purposes of the Colorado River system as specified in statute, judicial decisions, international treaties, and existing legal and operational requirements. An ecosystem-based alternative would also include problematic cuts to water allocations and implementation of implausible water conservation measures. Any operation would need to meet the applicable ecosystem-based requirements under applicable law or would require extensive and contentious modifications to law and contracts to be implementable.

S.6.3 One-Dam Alternative

Reclamation received comments related to one-dam alternatives focused on prioritizing the preservation of one dam and its reservoir—either Hoover Dam/Lake Mead or Glen Canyon Dam/Lake Powell—over the other. The majority of commenters supported an alternative that would prioritize filling Lake Mead, either by bypassing or decommissioning Glen Canyon Dam. Several commenters referenced maintaining Lake Powell at 3,550 feet and sending all excess water to Lake Mead. Others noted that low water levels in Lake Powell could result in additional resources emerging from Glen Canyon and called for these impacts to be considered. Additionally, three commenters expressed support for a "Grand Canyon Restoration Alternative"—such as a bypass tunnel around Glen Canyon Dam—to ensure high-flow experiments that protect both ecosystem and cultural resources, while four commenters supported preserving Lake Powell for recreation.

This alternative was not advanced because prioritizing one dam over the other would not yield an integrated, resilient system. Such a focus would undermine the balanced operations required to meet water delivery, environmental, and legal obligations under the Post-2026 action. Reclamation operates and maintains the two dams and reservoirs consistent with Law of the River, including the Boulder Canyon Project Act of 1928 that authorized the construction of Hoover Dam and the CRSP Act of 1956 that authorized the construction of Glen Canyon Dam, and all acts amendatory and supplemental. A one-dam alternative would require such extensive statutory modifications or amendments that it is unlikely to be acceptable among stakeholders and would be inconsistent with federal law.

S.7 References

Bureau of Reclamation (Reclamation). 2007a. Final Environmental Impact Statement: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Washington, D.C. Internet website: https://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html.

_____. 2007b. Record of Decision: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Washington, D.C. Internet website: https://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf.

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Appendix T

Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028

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T1 Modeling Assumptions for Anticipated Operating Guidelines for 2027-2028

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
AAC	All-American Canal
CCS	Continued Current Strategies
CRSP	Colorado River Storage Project
CRSS	Colorado River Simulation System
CY	calendar year
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
EOCY	end of calendar year
EOWY	end of water year
ICS	intentionally created surplus
kaf	thousand acre-feet
LTEMP	Long-Term Experimental and Management Plan
Maf	million acre-feet
NIB	Northerly International Boundary
SIB	Southerly International Boundary
U.S.	United States
WY	water year

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Appendix T. Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028

T.1 Introduction

As described in **Chapter 2**, Description of Alternatives, the Preferred Alternative is a 10-year decision framework through 2036. The decision framework establishes operational principles, sideboards (key thresholds and ranges for operational elements), and a process that would govern development and issuance of operating guidelines covering anticipated 2-year intervals, unless consensus-based agreements provide for a longer duration.

As of the date of this Final EIS, the anticipated guidelines for the first operating interval (2027 and 2028) are still being refined. These anticipated guidelines are based on extensive engagement with the Basin States and incorporate tribal input. For the purpose of this appendix, these anticipated guidelines are referred to as "2027-2028 Operating Guidelines." For the purpose of describing the potential upcoming operating guidelines and their associated impacts, a preliminary description and analysis of the 2027-2028 Operating Guidelines is included in this appendix. This appendix also analyzes how the impacts of the 2027-2028 Operating Guidelines compare to those of the Representative Preferred Alternative.

T.2 Preliminary Description of 2027-2028 Operating Guidelines

The four operational elements for the 2027-2028 Operating Guidelines are described in the subsequent sections. The specific Colorado River Simulation System (CRSS) modeling assumptions are provided in **Appendix T, Attachment T1**.

T.2.1 Guidelines to Reduce or Increase Deliveries from Lake Mead

Shortage Conditions

The 2027–2028 Operating Guidelines include a total Lower Basin shortage volume of 1.5 million acre-feet (maf) (inclusive of Mexico) in both 2027 and 2028.[1] Shortages above 1.5 maf are not modeled as shown in **Figure T-1**; however; if Lake Mead is projected to decline below elevation 1,000 feet during any 12-month period, consultation would occur to evaluate whether additional

[1] Based on the initial conditions, all 400 simulated futures apply a total Lower Basin shortage of 1.5 maf in 2027. The maximum December 2027 Lake Mead elevation across all 400 futures is 1,106 feet. As such all 400 simulated futures also apply a total Lower Basin shortage of 1.5 maf in 2028.

actions are necessary to reduce the risk of Lake Mead declining below elevation 950 feet. The modeled shortage volume is distributed among the Lower Division States (see **Table T-1**) consistent with the Lower Division States May 1 proposal.

Figure T-1
Shortage Guidelines to Reduce Deliveries from Lake Mead, 2027-2028 Operating Guidelines

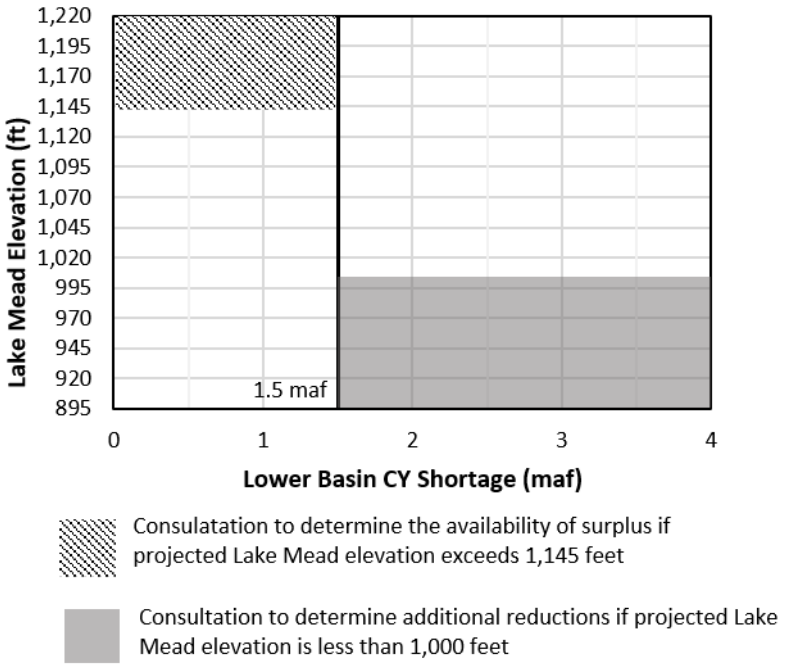


Table T-1
Shortage Distribution, 2027-2028 Operating Guidelines

Entity	Shortage (kaf)	Shortage (%)
Arizona	760	43.33
California	440	36.67
Nevada	50	3.33
Mexico	250	16.67

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States (U.S.) policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

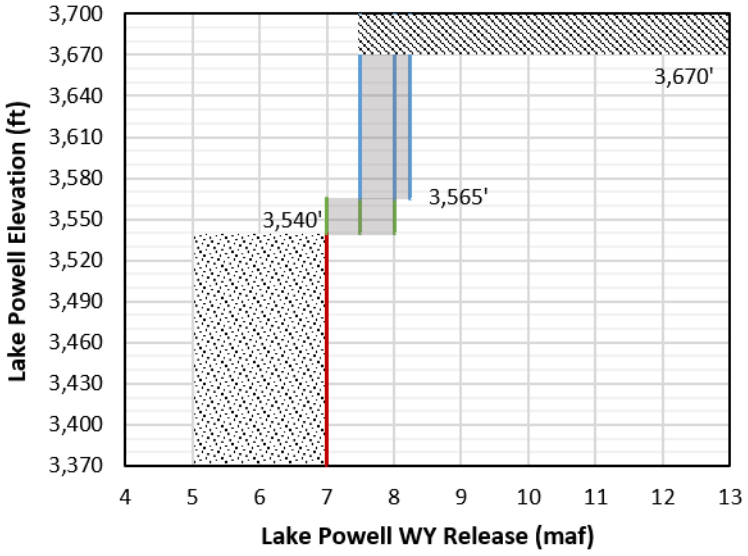
Normal and Surplus Conditions

If Lake Mead is projected to exceed elevation 1,145 feet, consultation regarding reduced shortage volumes or the availability of Surplus would occur. As described in footnote 1, the maximum December 2027 elevation is 1,106 feet; thus, neither Normal nor Surplus conditions are modeled in the analysis of the 2027-2028 Operating Guidelines.

T.2.2 Coordinated Reservoir Operations (Lake Powell and Lake Mead)

In 2027 and 2028, the annual water year releases from Lake Powell are determined based on projected reservoir conditions at the beginning of the water year, with the potential for adjustments during the water year in response to changing hydrologic conditions. These operations are designed to preserve the operational flexibility to protect critical infrastructure at Glen Canyon Dam and meet other operational objectives consistent with applicable federal law. The operations are summarized below and depicted in **Figure T-2.**

Figure T-2
Coordinated Operations of Lake Powell and Lake Mead, 2027-2028 Operating Guidelines



Equalization releases occur when the computed 602(a) Storage volume is exceeded. Hatching indicates the approximate corresponding Lake Powell elevation range.

WY release is selected from canditage releases by selecting the maximum release that maintains a projected elevation of at least 3,510' during the WY.

At any elevation, the release may be adjusted down to a minimum of 6.0 maf or 5.0 maf if Lake Powell is projected to decline below 3,510' or 3,500', respectively.

Primary Operations

Initial Water Year Release

The initial water year release is selected from a set of potential release volumes corresponding to the October 1 Lake Powell elevation as shown in **Table T-2** and **Figure T-2**. Potential release volumes are first evaluated to identify those projected to maintain a Lake Powell elevation of at least 3,510 feet during the following spring. The initial release is then selected from among those potential release volumes to preserve operational flexibility, allowing releases to be adjusted upward or downward over the course of the water year as hydrologic conditions evolve. The next section describes the potential adjustments to this initial water year release volume during the water year in response to changing hydrologic conditions.

When the October 1 Lake Powell elevation is below 3,540 feet, the modeled implementation evaluates an initial water year release of 7.0 maf. If that release is projected to result in Lake Powell declining below elevation 3,510 feet, the determination of the water year release is deferred until April, and monthly releases are adjusted to maintain elevation 3,510 feet. In April, the water year release is set, likely between 6.0 and 7.0 maf, contemporaneously with the additional releases from Colorado River Storage Project (CRSP) Upper Initial Units to protect critical infrastructure at Glen Canyon Dam, as described in the *Mid-Year Release Adjustments* section and in **Section T.2.4**.

Table T-2
Potential Initial Water Year Releases by Lake Powell Pool Elevation, 2027-2028 Operating Guidelines

Lake Powell October 1 Pool Elevation (feet)	Potential Initial Lake Powell Water Year Releases (maf)
> 3,565	8.23, 8.0, and 7.5
3,565 to 3,540	8.0, 7.5, and 7.0
< 3,540	7.0

Mid-Year Release Adjustments

There is potential for either an upward or a downward mid-year adjustment to the initial water year release. For modeling purposes, these adjustments occur in April.

An upward adjustment occurs if the end of water year (EOWY) projected Lake Powell elevation exceeds elevation 3,565 feet. In this case, the initial water year release is increased by half of the projected storage above elevation 3,565 feet, up to a maximum water year release of 12.0 maf.

A downward adjustment is evaluated to reduce the risk that Lake Powell will decline below elevation 3,510 feet during the next spring. If the projected Lake Powell elevation in the next spring is below 3,510 feet, the volume needed to maintain 3,510 feet is determined and used to adjust releases. First, the Lake Powell water year release is reduced to 7.0 maf if the initial release was greater than 7.0 maf. If additional reductions are necessary to meet the volume needed to maintain 3,510 feet, then the Lake Powell release is further reduced while CRSP Upper Initial Unit releases are increased. There is

an attempt to maintain a 1:1 ratio between the additional Lake Powell release reductions and the increased CRSP Upper Initial Unit releases, subject to a maximum CRSP Upper Initial Units release of 1.0 maf and a minimum Lake Powell water year release of 6.0 maf. The ***Infrastructure Protection and Other Considerations*** section describes the potential to reduce releases below 6.0 maf.

Coordination at High Elevations

For modeling purposes, a determination to potentially increase releases for the purpose of equalizing storage between Lake Powell and Lake Mead is made for the upcoming year if, on October 1, the net storage of all CRSP reservoirs exceeds the 602(a) storage volume and Lake Powell storage is greater than Lake Mead storage. The 602(a) storage volume is computed using the parameters from the 2007 Final EIS. **Appendix J**, Sensitivity Analysis – Effects of Assumed Parameter Values on 602(a) Storage, describes the 602(a) storage calculation and documents the parameters used in the 2007 calculation, which are also used in this analysis.

Infrastructure Protection and Other Considerations

If Lake Powell is projected to decline below elevation 3,510 feet during the current water year, annual releases may be reduced to as low as 6.0 maf. If Lake Powell is projected to decline below elevation 3,500 feet after these reductions are considered, water year releases may be further reduced to as low as 5.0 maf to protect critical Glen Canyon Dam infrastructure, subject to consultation. Monthly releases are adjusted to protect 3,510 and 3,500 feet subject to a minimum daily release established under the Long-Term Experimental and Management Plan.

T.2.3 Storage and Delivery of Conserved System and Non-System Water

The following sections reflect concepts included in the Lower Division States May 1 proposal. There are additional details on the specific modeling assumptions for the storage and delivery of conserved system and non-system water included in **Attachment T1**.

Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 5.3 maf, which includes the storage of pre-2027 Intentionally Created Surplus (ICS) except for System Efficiency ICS. Annual total and state-based limits for conservation volumes and delivery of conserved water are presented in **Table T-3**. All conserved water stored in Lake Mead would be included in determinations of equalization releases from Lake Powell and in projections of Lake Mead's elevation for consultations regarding additional/reduced Lower Basin shortage or availability of Lower Basin surplus. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users.

Table T-3
Volume Limitations of Storage and Delivery of Conserved Water, 2027-2028 Operating Guidelines

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Delivery (kaf)	Maximum Cumulative 2027-2028 Delivery (kaf)
Arizona	125	1,000	300	800
California	400	2,000	400	
Nevada	125	800	300	
Mexico[1]	250	1,500	N/A[2]	160
Total	**900**	**5,300**	**1,160**	**960**

1) Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
2) There is an assumed maximum cumulative delivery to Mexico of 160 kaf for 2027–2028. No annual maximum is specified; the annual delivery is constrained only by the two-year cumulative limit of 160 kaf.

Water users could contribute or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool (**Table T-3**) and the elevation constraints described below. At the time the water is conserved, a one-time 10 percent system assessment would be applied, followed by an annual 3 percent evaporation deduction calculated based on the volume remaining in the Lake Mead mechanism at the end of the preceding calendar year.

Delivery of conserved water would be prohibited if Lake Mead begins the year with a pool elevation below 1,000 feet. For modeling purposes, if the beginning-of-year pool elevation is between 1,000 feet and 1,025 feet, delivery volumes are proportionally reduced so that the forecasted end of calendar year pool elevation does not fall below 1,000 feet. The cumulative delivery to the Lower Division States is limited to 800 thousand acre-feet (kaf) through the end of 2028. Additionally, deliveries from the Lake Mead mechanism would be limited to ensure that a state's annual apportionment or Mexico's annual allotment is not exceeded.

Lake Mead Mechanism (Federally Managed Water Resources Pool)

Although not included in this analysis, the 2027-2028 Operating Guidelines are anticipated to include a Federally Managed Water Resources Pool. For more information on the Federally Managed Water Resources Pool, see **Chapter 2**, Description of Alternatives, **Section 2.4.3.3.3**. The modeling of the Representative Preferred Alternative includes representative modeling of this pool.

Treatment of Pre-2027 Intentionally Created Surplus

For modeling purposes, ICS created under the 2007 Interim Guidelines, except for System Efficiency ICS, that remains in Lake Mead in 2027 is transferred to the Post-2026 Lake Mead water

user-controlled mechanism immediately and would be subject to all provisions described in the previous section.

System Conservation

As described in the Lower Division States May 1 proposal the Lower Division States intend to contribute a cumulative minimum of 700 kaf of system conservation through 2028. For modeling purposes, the 700 kaf is allocated as 300 kaf from Arizona, 300 kaf from California, and 100 kaf from Nevada. Each state's contribution is assumed to be split equally between 2027 and 2028. These volumes are separate from ICS, not stored in individual state pools, and in addition to the previously described shortage volumes (**Section T.2.1**).

T.2.4 Additional Activities Above Lake Powel

Upper Basin Conservation

No Upper Basin conservation is assumed to occur in the analysis of the 2027-2028 Operating Guidelines.

Releases to Protect Glen Canyon Dam

Releases from the CRSP Upper Initial Units to protect critical Glen Canyon Dam infrastructure would be considered, after appropriate consultations, within their RODs and contingent on hydrologic conditions, if Lake Powell is projected to go below elevation 3,510 feet. For modeling purposes, increased CRSP Upper Initial Unit releases occur contemporaneously with a reduction in the Lake Powell water year release below 7.0 maf. There is an assumed maximum additional CRSP Upper Initial Unit release of 1.0 maf. Releases would consider historical practices and volumetric reductions in Lake Powell releases. For modeling purposes, there is an attempt to maintain a 1:1 ratio between the Lake Powell release reductions below 7.0 maf and the increased CRSP Upper Initial Unit releases. Should Lake Powell begin to recover sufficient elevation, Reclamation would consult regarding opportunities for recovery of volumes of previous releases from the CRSP Upper Initial Units.

T.3 Analysis of 2027-2028 Operating Guidelines

This section analyzes the potential impacts associated with implementation of the 2027–2028 Operating Guidelines on hydrologic resources, water deliveries from the mainstream Lower Colorado River, and other applicable resources. The analyses in these sections mirror those include in **Chapter 3**, Affected Environment and Environmental Consequences, **Section 3.2**, Hydrologic Resources, and **Section 3.3**, Water Deliveries, and their corresponding Technical Appendices, **TA 3**, Hydrologic Resources, and **TA 4**, Water Deliveries, respectively.

To provide context, the analysis compares the 2027–2028 Operating Guidelines (described in **Section T.2**) with the Continued Current Strategies (CCS) Comparative Baseline scenario (summarized in **Chapter 3, Table 3.2**), the No Action Alternative (described in **Appendix S,** Additional Description of Alternatives), and the Representative Preferred Alternative (described in **Chapter 2**). These comparisons illustrate where the impacts associated with the 2027–2028

Operating Guidelines fall within the range of impacts analyzed for the Representative Preferred and No Action Alternatives in the Final EIS. As with the rest of the analysis in the Final EIS, the CCS Comparative Baseline scenario is provided to assess the impacts if operations were to continue under the current direction and strategies.[2] While the CCS Comparative Baseline is not an action alternative, it is a contemporary set of operations that stakeholders are familiar with that can be used to comparatively evaluate the performance of the alternatives.

T.3.1 Methodology

The analysis presented in this appendix is based on output from the CRSS, Reclamation's long-term planning model for the Colorado River Basin. CRSS simulates Basin conditions throughout the 2027–2060 Final EIS analysis period, accounting for hydrologic uncertainty while generating monthly projections of reservoir elevations, releases, river flows, and other operational metrics. Additional information about the No Action Alternative, CCS Comparative Baseline and Representative Preferred Alternative modeling assumptions can be found in **Appendix A**, CRSS Model Documentation and **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water. **Attachment T1** details the 2027-2028 Operating Guidelines modeling assumptions.

The comparisons presented in this appendix are based on the Decision Making under Deep Uncertainty (DMDU) framework used in this Final EIS. DMDU is a non-probabilistic evaluation framework that compares alternatives across a broad range of plausible future conditions and evaluates their performance under varying hydrologic conditions. Additional background and technical information on the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach.

Analyses of the 2027–2028 Operating Guidelines are based on results for 2027–2028, whereas analyses of the CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative are based on the full 34-year Final EIS analysis period (2027–2060).

Results are summarized using conditional boxplots and summary statistics. Conditional boxplots group results by the preceding 3-year average Lees Ferry natural flow to facilitate comparisons among alternatives under similar hydrologic conditions (for example, average or dry conditions). Each figure includes results from all analysis years across 400 simulated futures, representing 800 data points for the 2027–2028 Operating Guidelines (two years) and 13,600 data points (34 years) for each of the CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative. Additional guidance for interpreting these figures is provided in **Chapter 3**, Affected Environment and Environmental Consequences, **Section 3.2.6**. Statistical summary tables that correspond to every boxplot in the following sections are included at the end of this appendix.

The difference in the underlying volume of data included for the 2027-2028 Operating Guidelines analysis versus the Representative Preferred Alternative may lead to the conclusion that the two-year operations would result in substantively different performance than the Representative Preferred

[2] This framework relies on strategies and agreements that expire in 2026, including the 2007 Interim Guidelines (as amended), the 2019 DCP, Minute 323 of the 1944 Water Treaty, and other agreements.

Alternative, but this is not an appropriate conclusion. The results over the shorter period are heavily influenced by the initial reservoir conditions in 2027, which are similar to what the 2027-2028 Operating Guidelines will be reacting to. In contrast, the results for Representative Preferred Alternative effectively incorporate hundreds of different initial reservoir conditions, including elevations significantly higher and significantly lower than current conditions. The expanded range of potential reservoir conditions is useful for evaluating a wide range of impacts, but not necessary for evaluating the range of potential near-term impacts. The relevant information is that, given the expected conditions in 2027, the potential impacts of the 2027-2028 Operating Guidelines are within the range of potential impacts associated with the Representative Preferred Alternative.

T.3.2 Hydrologic Resources

Impact Analysis Area

The geographic scope of the hydrologic resources analysis is the Colorado River corridor from the upstream limits of full pool elevation of Lake Powell to the downstream limits of the Southerly International Boundary (SIB). Reservoirs upstream of Lake Powell are operated pursuant to their own Records of Decision, which are not altered by the proposed alternatives.

Impact Indicators

The following indicators were used to assess impacts on hydrologic resources:

- **Reservoir elevations**: impacts on reservoir elevations due to operational activities
- **System storage**: impacts on system storage due to operational activities
- **Reservoir releases:** impacts on reservoir releases due to operational activities
- **River flows:** impacts on river flows due to operational activities
- **Groundwater**: qualitative impacts on groundwater adjacent to reservoirs and river reaches due to operational activities

Reservoir Elevation

This section evaluates how operational activities would affect reservoir elevations by comparing the 2027–2028 Operating Guidelines, CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative using the following metrics:

- Lake Powell pool elevations
- Lake Mead pool elevations

Lake Powell

This section presents a comparison of the 2027–2028 Operating Guidelines with the CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative with respect to minimum water year (WY) and EOWY elevations at Lake Powell. A description of critical Lake Powell elevations is listed in **TA 3**, Hydrologic Resources, **Table TA 3-2**. The total live storage capacity of Lake Powell at the full pool elevation of 3,700 feet is 23.31 maf (excluding approximately 1.9 maf of flood control space).

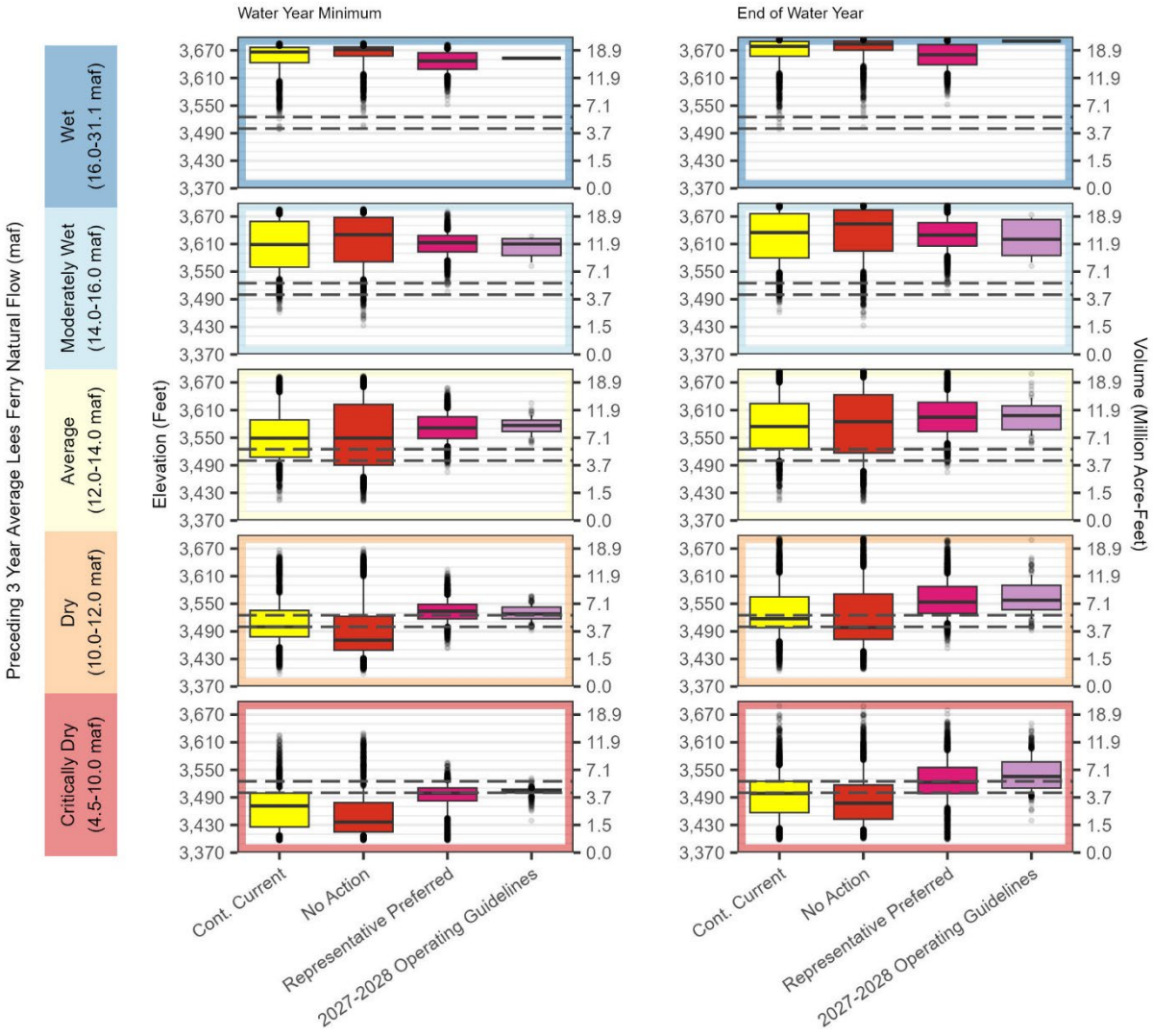
Figure T-3 shows minimum WY elevations and EOWY elevations at Lake Powell (feet) for each alternative using conditional boxplots. The boxplots show how the alternatives perform under varying hydrologic conditions, defined by the preceding three-year average of Lees Ferry natural flow. The bottom and top of each box captures the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and outliers are shown as dots. To enable easier comparison of all flow categories, the vertical axes may have been truncated at the high end, and some outliers may have been omitted. Statistical summaries of the left and right columns are provided in **Table T-5** and **Table T-6** at the end of this appendix**.**

In each flow category shown in the boxplots, the critical elevation thresholds of 3,525 feet and 3,500 feet are identified with dashed lines. These elevations are important because they provide a 10-foot and a 35-foot buffer above 3,490 feet—the elevation below which water can only be released through the river outlet works. Operating below 3,490 feet limits the volume of water that can be released, since water can only pass through the river outlet works. As described in **Chapter 1**, Purpose and Need, **Section 1.8.4.1**, there are infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs. There are additional impacts to hydropower associated with operating below 3,490 feet as this is minimum power pool.

The 2027-2028 Operating Guidelines result in median WY minimum elevations of 3,577, 3,528, and 3,505 feet in the Average, Dry, and Critically Dry Flow Categories, respectively. In the Critically Dry Flow Category, the 10th percentile minimum elevation falls below 3,500 feet, with outliers dropping below 3,500 feet in the Dry Flow Category. The median WY minimum elevations of the 2027-2028 Operating Guidelines are similar to those of the Representative Preferred Alternative, with all of the 2027-2028 Operating Guidelines WY minimum elevations falling within the range of elevations from the Representative Preferred Alternative. The modeled Lake Powell operations in the 2027-2028 Operating Guidelines, which adjust to maintain elevation 3,510 feet, are effective at avoiding elevation 3,500 feet. Only the outliers below the 10th percentile in the Dry Flow Category and the 25th percentile and below in the Critically Dry Flow Category fall below elevation 3,500 feet.

For the EOWY elevations at Lake Powell, the 2027-2028 Operating Guidelines result in median elevations of 3,598, 3,558, and 3,535 feet in the Average, Dry, and Critically Dry Flow Categories, respectively. Similar to the WY minimum elevations, the 10th percentile EOWY elevation falls below 3,500 feet in the Critically Dry Flow Category, whereas elevations below 3,500 feet occur only as outliers in the Dry Flow Category. Median EOWY elevations are slightly higher than those of the Representative Preferred Alternative in the Average, Dry, and Critically Dry Flow Categories. Overall, the WY minimum and EOWY elevations in the 2027-2028 Operating Guidelines fall within the range of the elevations in the Representative Preferred Alternative.

Figure T-3
WY Minimum and EOWY Elevations and Storage Volumes of Lake Powell



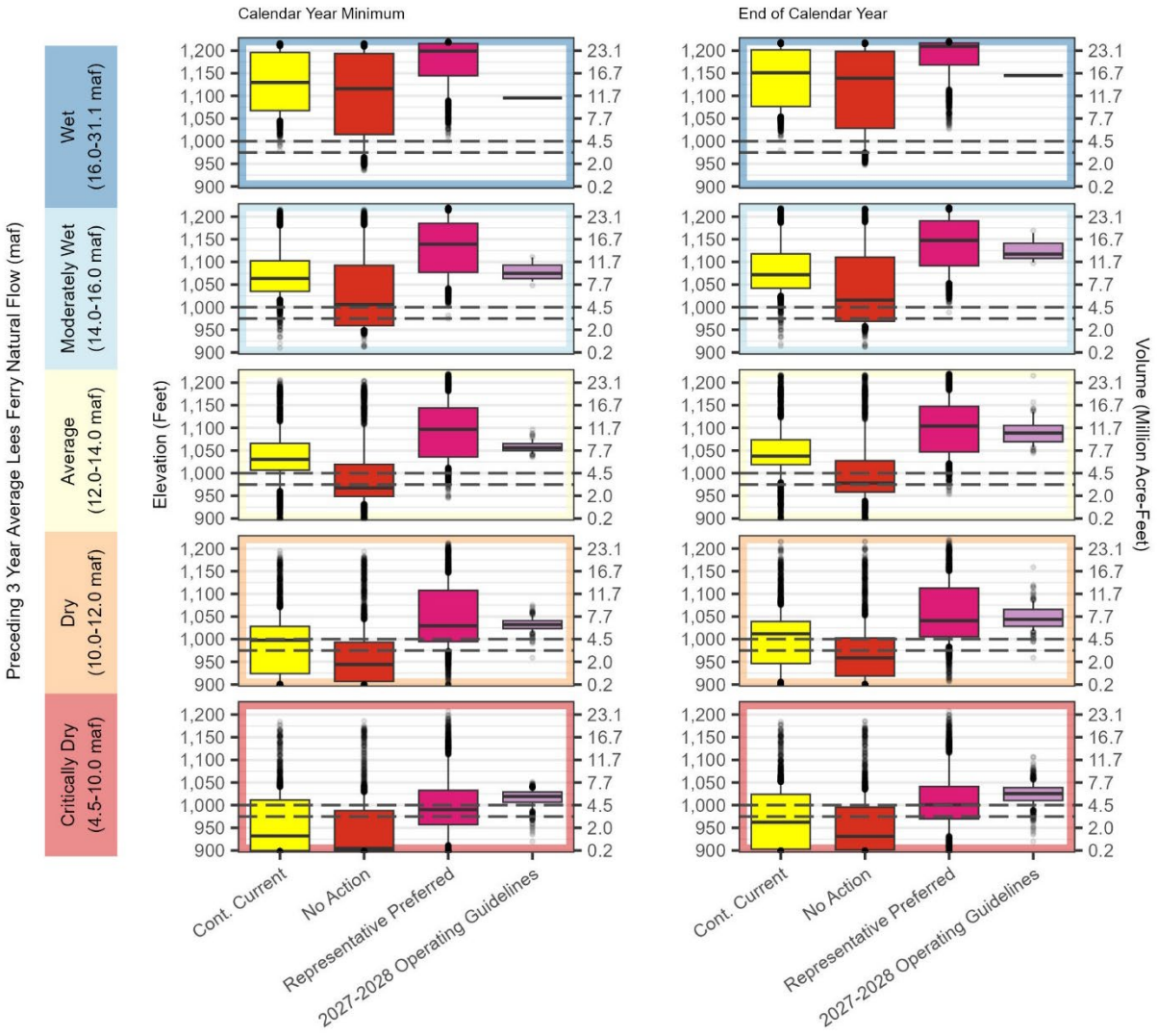
Lake Mead

This section presents a comparison of the 2027–2028 Operating Guidelines with the CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative with respect to minimum calendar year (CY) and end of calendar year (EOCY) elevations at Lake Mead. Critical elevations at Lake Mead listed in **TA 3**, Hydrologic Resources, **Table TA 3-5** preserve infrastructure and ensure Hoover Dam continues to operate under its intended design for purposes of downstream water releases. The total live storage capacity of Lake Mead at the full pool elevation of 1,219.6 feet is 26.12 maf (excluding approximately 1.5 maf of Flood Control storage available above the maximum operating elevation).

Figure T-4 shows minimum CY and EOCY elevations at Lake Mead (feet) for each alternative using conditional boxplots. Statistical summaries of data are provided in **Table T-7** and **Table T-8**

at the end of this appendix. In each flow category, the critical thresholds of 1,000 feet and 975 feet are identified with dashed lines. These elevations are important because they provide a 50-foot and a 25-foot buffer from 950 feet—the elevation below which water can only be released through the intake towers, constraining both the volume of water able to be released as well as the ability to generate power. Lake Mead requires larger buffers above the hydropower and critical infrastructure elevations than Lake Powell because Reclamation is required to deliver water orders that have already been approved. As a result, there is generally less flexibility to adjust releases from Hoover Dam than from Glen Canyon Dam.

Figure T-4
CY Minimum and EOCY Elevations and Storage Volumes of Lake Mead



The 2027-2028 Operating Guidelines have median CY minimum elevations of 1,056, 1,032, and 1,019 feet in the Average, Dry, and Critically Dry Flow Categories, respectively. In the Critically Dry Flow Category, the 10th percentile elevation falls below 1,000 feet, with outliers dropping below 975 feet. In the Dry Flow Category, minimum elevations below 975 feet occur only as outliers. The

range of CY minimum elevations is much narrower than that of the Representative Preferred Alternative because the 2027-2028 Operating Guidelines boxplot includes data only for the two-year period, which is heavily influenced by the initial conditions as previously discussed. Additionally, the 2027-2028 Operating Guidelines model a total Lower Basin shortage of 1.5 maf, while the Representative Preferred Alternative models shortages up to 3.6 maf, which affects Lake Mead's elevation.

For the EOCY elevations at Lake Mead, the median EOCY elevations of the 2027-2028 Operating Guidelines are 1,089, 1,044, and 1,025 feet in the Average, Dry, and Critically Dry Flow Categories, respectively. Like the CY minimum elevations, in the Critically Dry Flow Category, the 10th percentile EOCY elevation falls below 1,000 feet, with outliers dropping below 975 feet. In the Dry Flow Category, EOCY elevations below 975 feet only occur as outliers. Overall, CY minimum and EOCY elevations at Lake Mead under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

System Storage

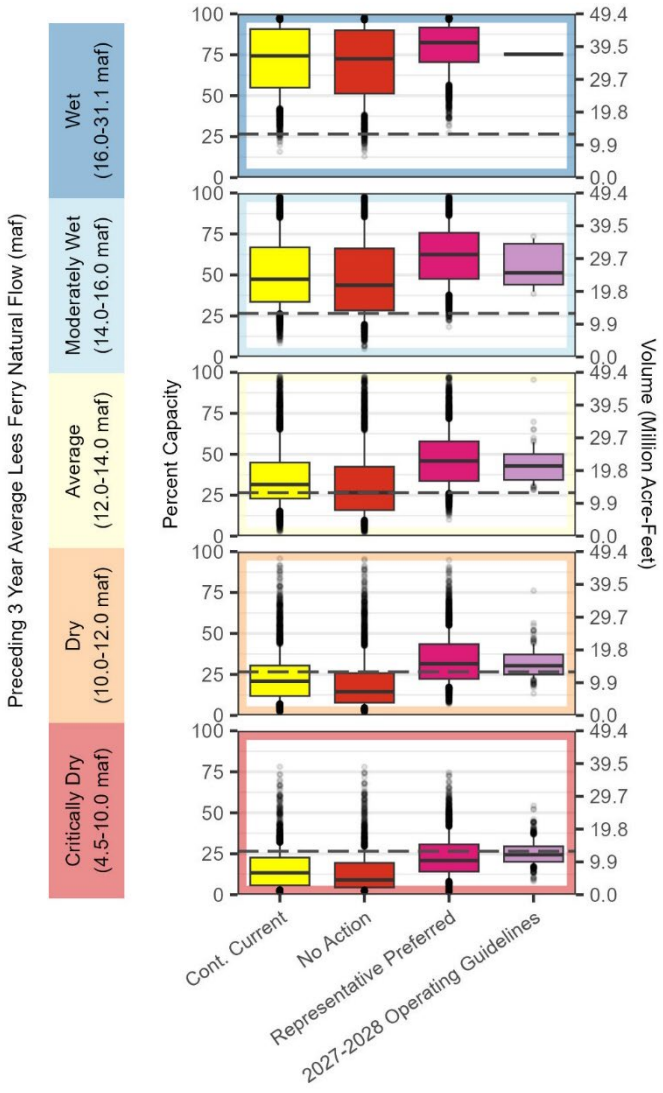
This section evaluates how operational activities would affect system storage by comparing the 2027–2028 Operating Guidelines, CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative using the EOWY combined system storage at Lake Powell and Lake Mead.

This metric provides insight into overall system conditions because Lake Powell and Lake Mead account for approximately 85 percent of the total storage volume in the major Colorado River system reservoirs. Excluding space allocated for surcharge and flood control, the live storage capacity is 23.31 maf at Lake Powell and 26.12 maf at Lake Mead, for a maximum combined live storage capacity of 49.43 maf.

Figure T-5 presents conditional boxplots of EOWY combined storage in Lake Powell and Lake Mead. The vertical axis shows combined percent full on the left and volume of storage on the right. A threshold line indicates the lowest observed EOWY combined storage, which occurred in September 2022, at 26.55 percent full (equivalent to 13.1 maf). A statistical summary of the data is provided in **Table T-9** at the end of this appendix.

The 2027-2028 Operating Guidelines result in a median EOWY combined storage at Lake Powell and Lake Mead of 42.9, 30.3, and 24.4 percent capacity in the Average, Dry, and Critically Dry Flow Categories, respectively. Compared to the Representative Preferred Alternative, the median combined storage is lower in the 2027-2028 Operating Guidelines in all flow categories except the Critically Dry Flow Category. The 25th percentile combined storage falls below the minimum observed combined storage in the Dry Flow Category, while the median combined storage falls below the minimum observed combined storage in the Critically Dry Flow Category. Overall, EOWY combined Powell and Mead storage under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-5
EOWY Combined Storage at Lake Powell and Lake Mead



Reservoir Releases

This section evaluates how operational activities would affect reservoir releases by comparing the 2027–2028 Operating Guidelines, CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative using the following metrics:

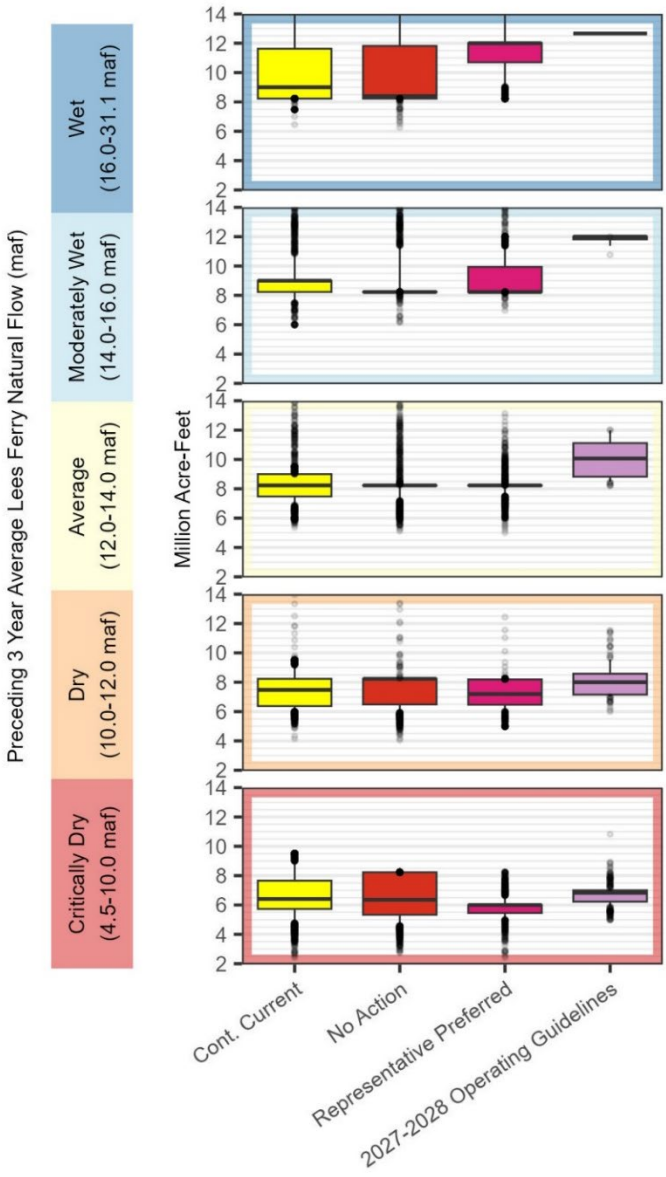
- WY Releases from Glen Canyon Dam
- 10-Year Releases from Glen Canyon Dam
- 10-Year Flows at Lee Ferry Compact Point
- CY Releases from Hoover Dam
- CY Releases from Davis Dam
- CY Releases from Parker Dam

Glen Canyon Dam

Releases from Glen Canyon Dam, at Lake Powell, are based on the operations as summarized in **Section T.2.2**.

Figure T-6 presents conditional boxplots of WY releases (maf) from Glen Canyon Dam. The y-axis has been truncated to facilitate easier comparison of the alternatives, see **Table T-10** at the end of this appendix for the full statistical summary.

Figure T-6
WY Releases from Glen Canyon Dam[3]



[3] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-10** for the full range of the data.

The 2027-2028 Operating Guidelines result in median WY Glen Canyon Dam release of 10.07, 8.00, and 6.83 maf in the Average, Dry, and Critically Dry Flow Categories, respectively. The median WY Glen Canyon Dam release in the 2027-2028 Operating Guidelines is higher than in the Representative Preferred Alternative in all flow categories. As previously discussed, the releases for the 2027-2028 Operating Guidelines are heavily influenced by initial conditions, and the number of data points analyzed compared to the other alternatives. The minimum WY Glen Canyon Dam release in the 2027-2028 Operating Guidelines is as low as 5.0 maf in the Critically Dry Flow Category. Overall, the WY Glen Canyon Dam release under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

Glen Canyon Dam 10-Year Releases

Figure T-7 presents conditional boxplots of cumulative 10-year releases from Glen Canyon Dam. The y-axis is truncated to enable easier comparison of alternatives. See **Table T-11** at the end of this appendix for the full statistical summary.

The 2027-2028 Operating Guidelines result in median 10-year releases from Glen Canyon Dam of 79.3, 77.0, and 77.6 maf in the Average, Dry, and Critically Dry Flow Categories, respectively. The median release volumes in the 2027-2028 Operating Guidelines are higher than the Representative Preferred Alternative in the Average, Dry and Critically Dry Flow Categories, largely due to the influence of initial conditions, which is even more influential in this metric, and the number of data points. The 10-year release volumes are all very similar since they are driven by the prior 9 or 8 years of historical flows. Overall, the 10-year releases from Glen Canyon Dam under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

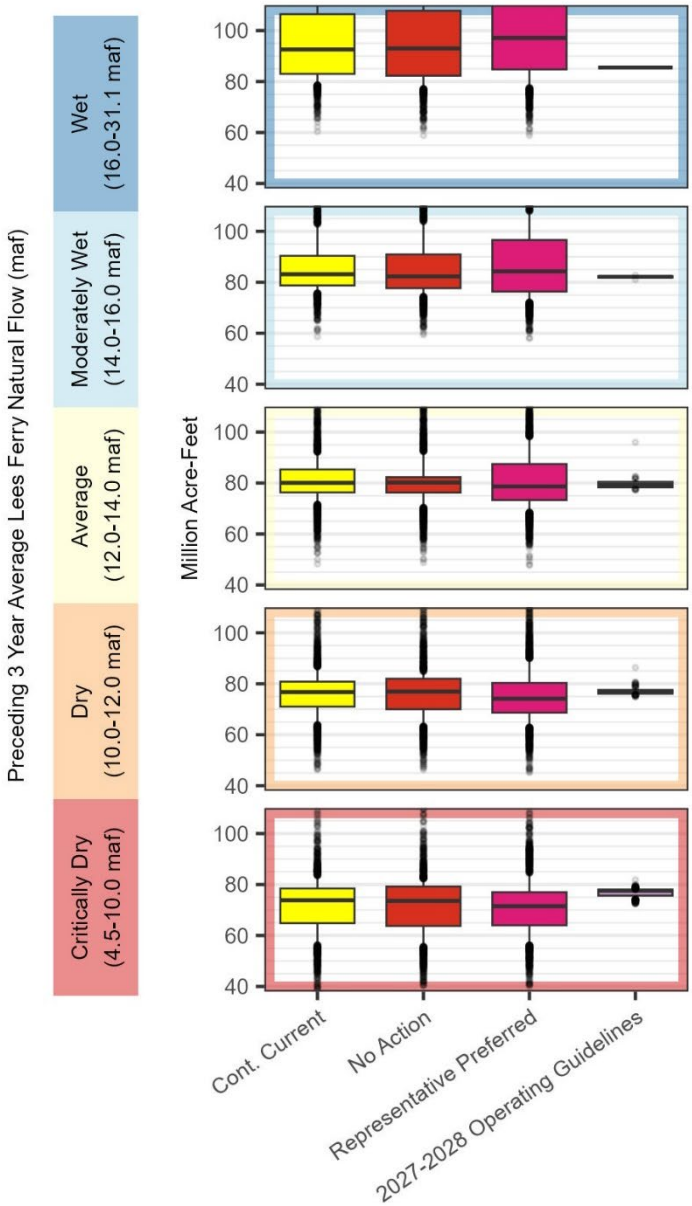
Cumulative 10-Year Lee Ferry Flows

The Lee Ferry Compact Point is the division point between the Upper Basin and the Lower Basin, as established by the 1922 Colorado River Compact. The Lee Ferry Compact point is in Arizona, approximately 17 miles downstream of Glen Canyon Dam and approximately 1 mile downstream of the confluence with the Paria River. Refer to **TA 3**, Hydrologic Resources, **Figure TA 3-2** in the Affected Environment Section for a map of the Lee Ferry Compact Point.

Figure T-8 presents conditional boxplots of cumulative 10-year Lee Ferry flow volumes (maf). In each flow category, 75.0 maf and 82.5 maf are shown with dashed lines**.** To facilitate easier comparison of alternatives, the y-axis is truncated. See **Table T-12** at the end of this appendix for the full statistical summary.

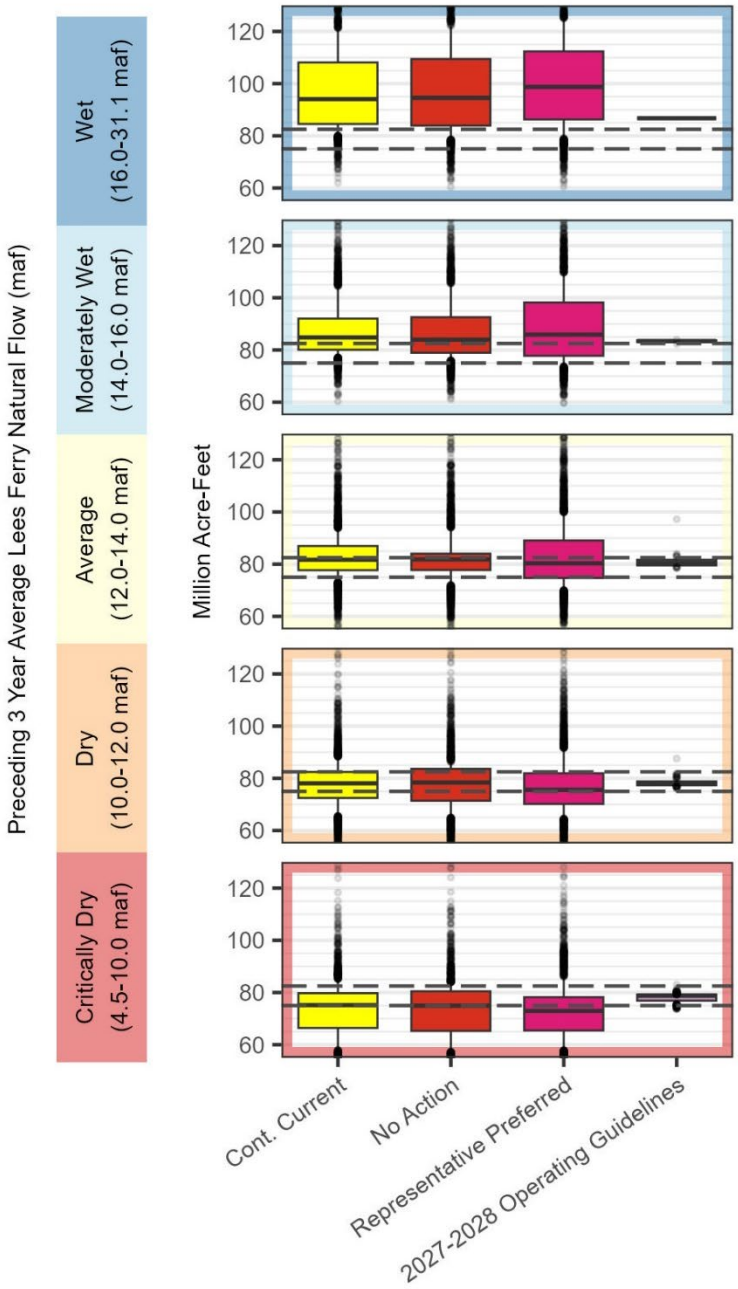
The 2027-2028 Operating Guidelines result in median 10-year cumulative Lee Ferry flow volumes of 80.5, 78.2, and 78.8 maf in the Average, Dry, and Critically Dry Flow Categories, respectively. These median volumes are below the 82.5 maf threshold, while only the outliers in the Critically Dry Flow Category fall below the 75 maf threshold. The 10-year cumulative Lee Ferry flow volumes are all very similar since they are driven by the prior 9 or 8 years of historical flows. Overall, the 10-year cumulative Lee Ferry flow volumes under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-7
10-Year Cumulative Releases from Glen Canyon Dam[4]



[4] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-11** for the full range of the data.

Figure T-8
Compact Point 10-Year Volume[5]

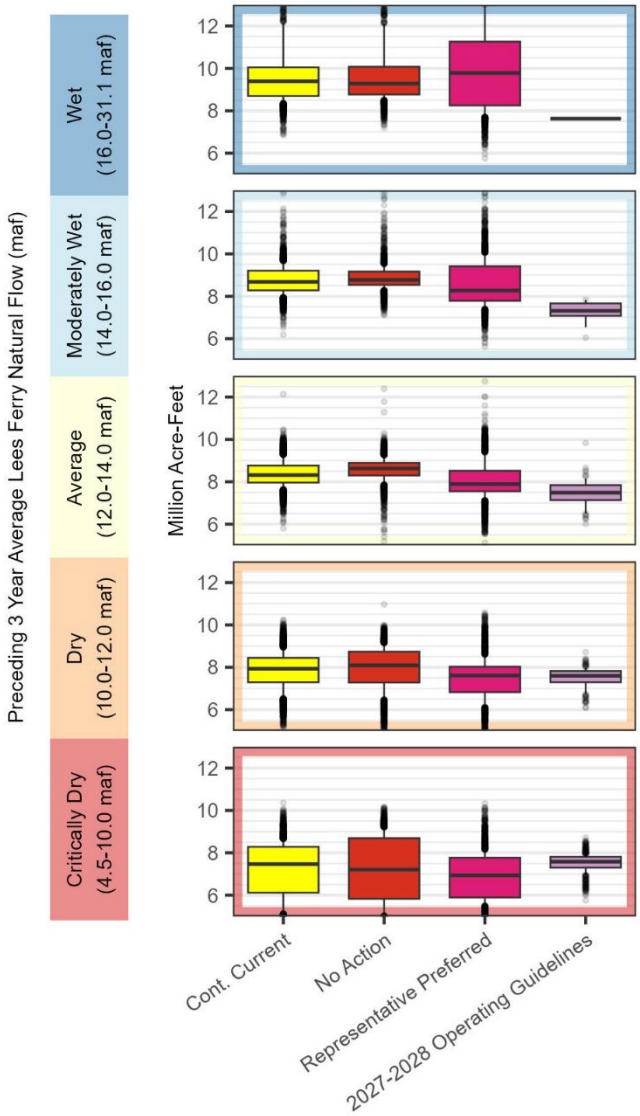


[5] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-12** for the full range of the data.

Hoover Dam

Releases from Hoover Dam, at Lake Mead, are based on downstream diversions and Lower Basin intervening flows. Diversions are impacted by the Lower Basin condition and the Lower Basin conservation, storage, and delivery of conserved system and non-system water. **Figure T-9** presents conditional boxplots of CY releases (maf) from Hoover Dam. The range of releases has been truncated to facilitate comparison of the alternatives, see **Table T-13** at the end of this appendix for the full range of data.

Figure T-9
CY Releases from Hoover Dam[6]



[6] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-13** for the full range of the data.

The 2027-2028 Operating Guidelines have median CY Hoover releases of 7.5, 7.6, and 7.6 maf in the Average, Dry, and Critically Dry Flow Categories, respectively. The median CY Hoover release under the 2027-2028 Operating Guidelines is lower than under the Representative Preferred Alternative in all flow categories except the Critically Dry Flow Category. The range of CY Hoover releases is much narrower than that of the Representative Preferred Alternative because the 2027-2028 Operating Guidelines only include data from the two-year period, which model a total Lower Basin annual shortage of 1.5 maf for all years and futures analyzed. In contrast, the Representative Preferred Alternative models shortages up to 3.6 maf, which explains the lower releases that are shown for it. Variability in Hoover releases is mainly driven by intervening inflows and diversions below Hoover. Overall, the CY Hoover release under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

Davis Dam

Releases from Davis Dam, at Lake Mohave, are based on target elevations defined by the existing rule curve (refer to **TA 6**, Water Quality). Inflows into Lake Mohave vary across alternatives, and because elevations are kept to the range determined by the rule curve, releases from Davis Dam subsequently vary across alternatives.

Figure T-10 presents conditional boxplots of CY releases from Davis Dam. The range of releases has been truncated to facilitate comparisons of alternatives, see **Table T-14** at the end of this appendix for the full statistical summary and full range of values.

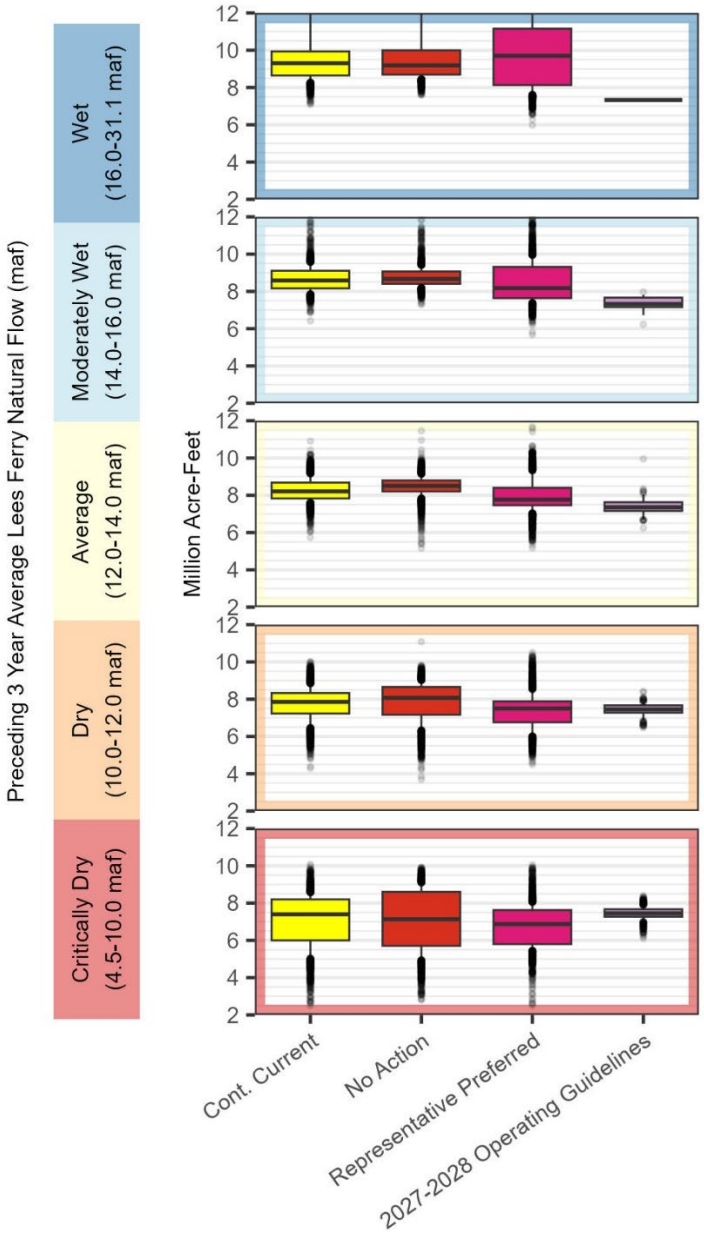
The 2027-2028 Operating Guidelines result in median CY Davis Dam releases of 7.4, 7.5, and 7.5 maf in the Average, Dry, and Critically Dry Flow Categories, respectively. Similar to Hoover releases, the median CY Davis release under the 2027-2028 Operating Guidelines is less than or equal to that under the Representative Preferred Alternative in all flow categories except the Critically Dry Flow Category. The boxplots for the 2027-2028 Operating Guidelines Davis release are similar to the Hoover release though there is slightly less variability. Variability in releases is driven by the same factors as the Hoover release (i.e., downstream diversions and intervening inflows). Overall, the CY Davis release under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

Parker Dam

Releases from Parker Dam, at Lake Havasu, are based on target elevations defined by the existing rule curve (refer to **TA 6**, Water Quality). Inflows into Lake Havasu vary across alternatives, and because elevations are kept to the range determined by the rule curve, releases from Parker Dam subsequently vary across alternatives.

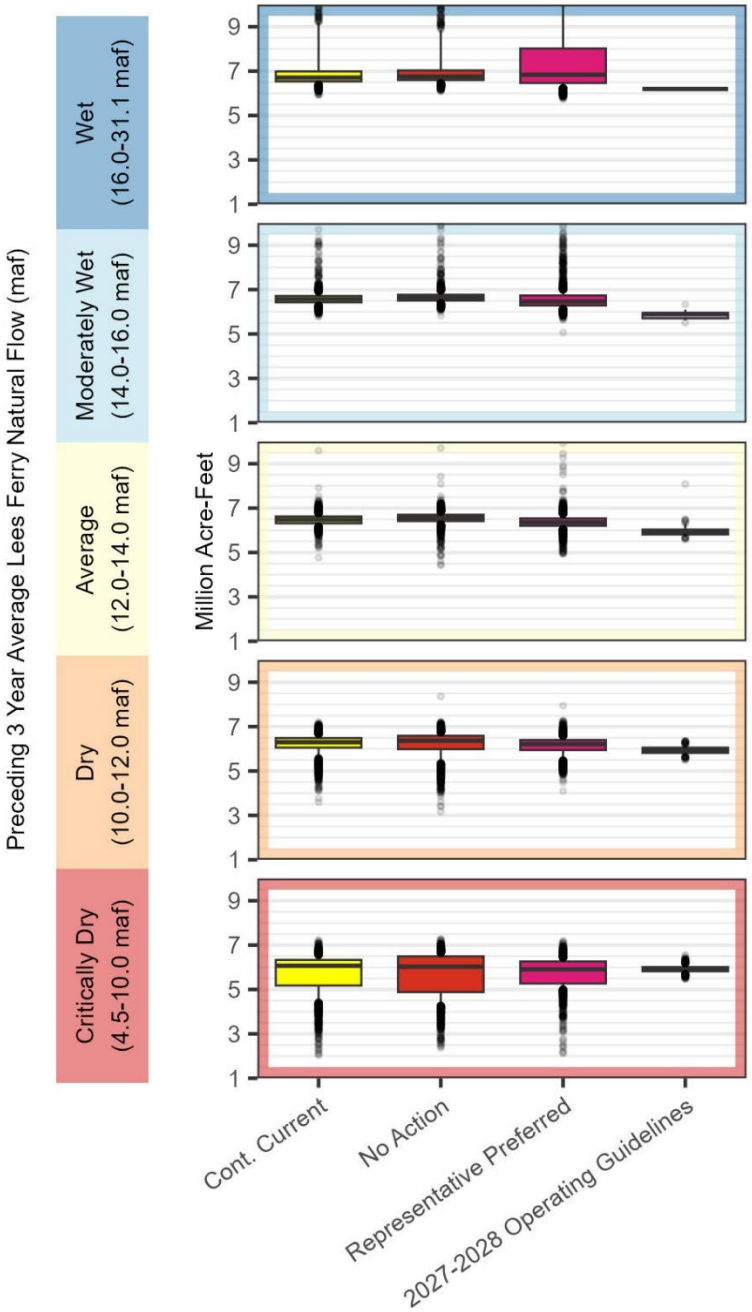
Figure T-11 presents conditional boxplots of CY releases from Parker Dam. The range of releases is truncated to facilitate comparisons between the alternatives, see **Table T-15** at the end of this appendix for the full statistical summary.

Figure T-10
CY Releases from Davis Dam[7]



[7] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-14** for the full range of the data.

Figure T-11
CY Releases from Parker Dam[8]



The 2027-2028 Operating Guidelines result in median CY Parker Dam releases of 5.9 maf in the Average, Dry, and Critically Dry Flow Categories. Similar to Hoover and Davis releases, the median CY Parker release under the 2027-2028 Operating Guidelines is lower than under the Representative Preferred Alternative in all flow categories except the Critically Dry Flow Category. The releases

[8] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-15** for the full range of the data.

from Parker Dam are affected by the assumed location (i.e., which CRSS water user) of the shortages and system conservation. **Attachment T1** provides details on these assumptions. Overall, the CY Parker release under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

River Flows

This section evaluates how operational activities affect river flows by comparing the 2027–2028 Operating Guidelines, CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative using the following metrics

- Annual Colorado River flows below Glen Canyon Dam
- Annual Colorado River flows below Hoover Dam
- Annual Colorado River flows below Davis Dam
- Annual Colorado River flows below Parker Dam
- Annual Colorado River flows at Imperial Dam
- Annual Colorado River flows below Imperial Dam
- Annual Colorado River flows below Morelos Diversion Dam

Reach 1: Glen Canyon Dam to Lake Mead

This reach of the river extends 292-miles from Glen Canyon Dam to Lake Mead through a series of narrow canyons, including Grand Canyon National Park. River flows in this reach primarily consist of controlled releases from Glen Canyon Dam at Lake Powell. Refer to **Section T.3.2** Reservoir Releases—Glen Canyon Dam, for the analysis of WY releases (**Figure T-6**) and 10-year cumulative releases (**Figure T-7**). While the results of the CRSS analysis are on an annual basis, monthly releases from Lake Powell at Glen Canyon Dam meet the 2016 LTEMP ROD (Reclamation 2016) minimum flows. Reclamation has the option to conduct high flow experiment releases from Glen Canyon Dam under certain conditions to reduce sediment deposition, which usually occurs in durations ranging from 60 hours to 10 days. Refer to **TA 5**, Geomorphology and Sediment, and **TA 8**, Biological Resources – Fish and Other Aquatic Species, for the analysis of high flow experiment flows from Glen Canyon Dam.

This reach also includes contributions from the Paria River and Little Colorado River, two perennial tributaries that discharge to the Colorado River between Glen Canyon Dam and Lake Mead. Based on historical USGS gage data, inflows from the Paria River and Little Colorado River make up approximately three percent of the total flow in this reach of the Colorado River (USGS 2025a). From 1906 to 2005, the annual inflow of the Paria River averaged 21.0 kafy and the Little Colorado River inflow averaged 180.0 kafy. Since 2007, the annual inflow from the Paria River averaged 17.0 kafy, and the Little Colorado River inflow averaged 274.0 kafy. Inflows from the Paria River and Little Colorado River were modeled in CRSS the same across alternatives.

Reach 2: Hoover Dam to Lake Mohave

This reach of the Colorado river) extends 67-miles from Hoover Dam at Lake Mead through Black Canyon, El Dorado Canyon, and Pyramid Canyon. Lake Mohave is on the downstream end of the reach, and acts hydraulically like a tailwater to Hoover Dam. River flows in this reach primarily

consist of releases from Hoover Dam, with small contribution from tributary inflows. According to the 2007 Final EIS, tributary inflows, mostly from side washes, comprise less than 1 percent of the total annual flow (Reclamation 2007a). Refer to **Section T.3.2** Reservoir Releases—Hoover Dam for the analysis of CY releases from Hoover Dam (**Figure T-9**).

Reach 3: Davis Dam to Lake Havasu

This reach of the Colorado River extends 84-miles from Davis Dam at Lake Mohave to Lake Havasu. River flows are primarily composed of releases from Davis Dam and tributary inflow from the Bill Williams River. Inflows from the Bill Williams River discharge directly into Lake Havasu and are regulated by the USACE operations of Alamo Dam. Annual inflow from the Bill Williams River averaged 102,000 af from 1906 through 2007, and 105,000 af from 2008 to 2022 (USGS 2025b).

Because releases from Davis Dam are the primary component that differs among alternatives, they are used as the basis for comparison. Refer to **Section T.3.2** Reservoir Releases—Davis Dam for the analysis of CY releases from Davis Dam (**Figure T-10**).

Reach 4: Parker Dam to Cibola Gage

This reach of the Colorado river extends 105-miles from Parker Dam at Lake Havasu to Reclamation's Cibola Gage. Flows in this reach primarily consist of releases from Parker Dam. Two major diversion dams are located in this reach of the river: Headgate Rock Dam and Palo Verde Diversion Dam. The impoundments of these dams are used to facilitate the diversion of water for the Colorado River Indian Tribes and Palo Verde Irrigation District.

The analysis of flows for this reach is based on CY release volumes from Parker Dam. Refer to **Section T.3.2** Reservoir Releases—Parker Dam for the analysis of CY releases from Parker Dam (**Figure T-11**).

Reach 5: Cibola Gage to Imperial Dam

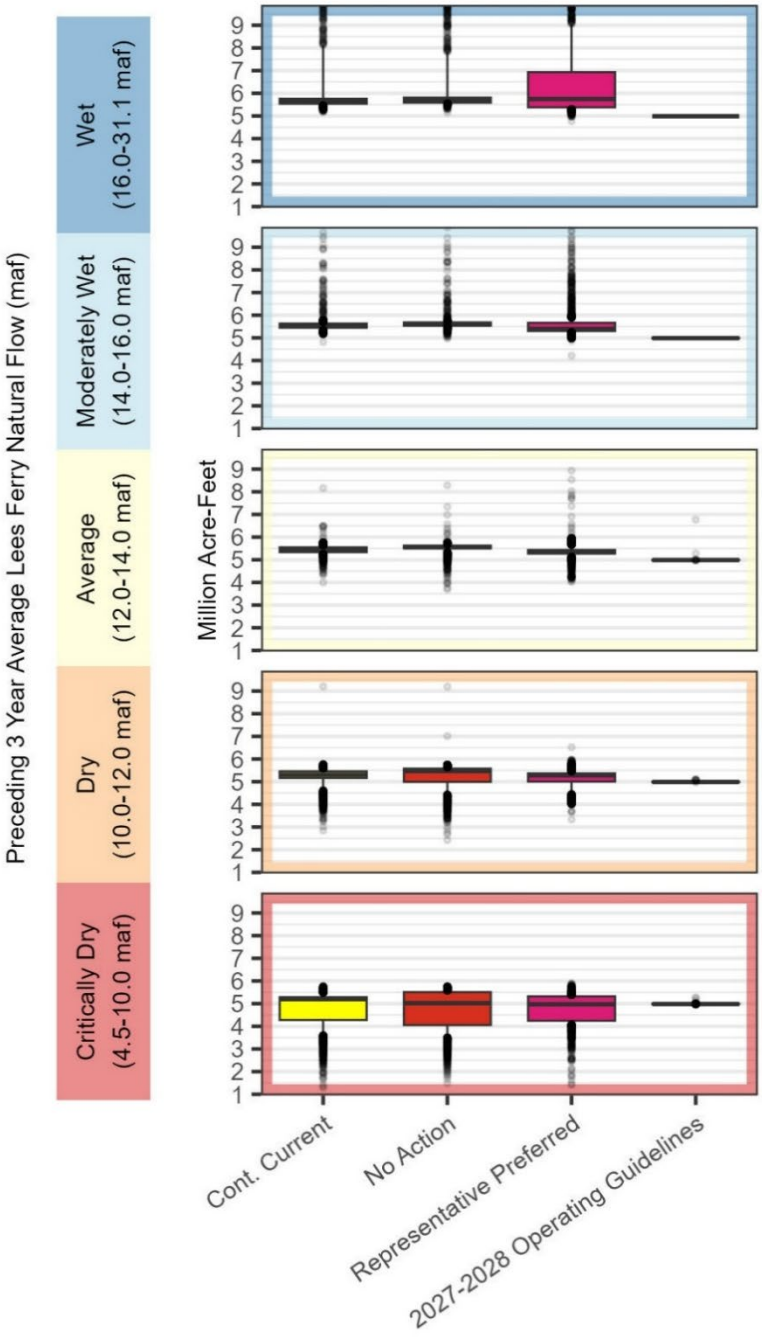
This reach of the river extends 38-miles from Reclamation's Cibola Gage to Imperial Dam at Imperial Reservoir. Flows in this reach consist primarily of releases from Parker Dam but are impacted by diversions and return flows. The Imperial Dam impoundment in this reach operates at a nearly constant elevation to meet water delivery requirements.

Figure T-12 presents conditional boxplots of annual flow volume at Imperial Dam. The range of volumes is truncated at the high end to facilitate comparisons between alternatives, see **Table T-16** at the end of this appendix for the full statistical summary.

The 2027-2028 Operating Guidelines result in median annual flow volume at Imperial Dam of 5.0 maf in the Average, Dry, and Critically Dry Flow Categories. The median annual flow volume at Imperial Dam under the 2027-2028 Operating Guidelines is less than or equal to that under the Representative Preferred Alternative in all flow categories. The annual flow volume boxplots at Imperial Dam for the 2027-2028 Operating Guidelines show variability only in the outliers, which are driven by intervening flows because releases from Hoover Dam are set to meet the downstream demands in consideration of the intervening flows. The annual flow volume at Imperial Dam is affected by the assumed location (i.e., which CRSS water user) of the shortages and system

conservation. **Attachment T1** provides details on these assumptions. Overall, the annual flow volume at Imperial Dam under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-12
Annual Flow Volume at Imperial Dam[9]



[9] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-16** for the full range of the data.

Reach 6: Imperial Dam to Northerly International Boundary
This reach of the Colorado river extends 26-miles from Imperial Dam to the Northerly International Boundary (NIB) between the U.S. and Mexico. Flows in this reach primarily consist of releases from Imperial Dam to meet downstream delivery requirements. They also include leakage from the All-American Canal (AAC) sluiceway gates and return flows from Imperial Dam diversions.

Figure T-13 presents conditional boxplots of annual flow volume below Imperial Dam. The range of volumes is truncated at the high end to facilitate comparisons between alternatives, see **Table T-17** at the end of this appendix for the full statistical summary

The 2027-2028 Operating Guidelines result in median annual flow volume below Imperial Dam of 1.0 maf in the Average, Dry, and Critically Dry Flow Categories. The median annual flow volume below Imperial Dam under the 2027-2028 Operating Guidelines is lower than under the Representative Preferred Alternative in the Wet flow category but slightly higher in all other flow categories. Differences in the median performance are due to the lower shortage volume (1.5 maf) under the 2027-2028 Operating Guidelines compared to the shortages up to 3.6 maf included in the Representative Preferred Alternative. Overall, the annual flow volume below Imperial Dam under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

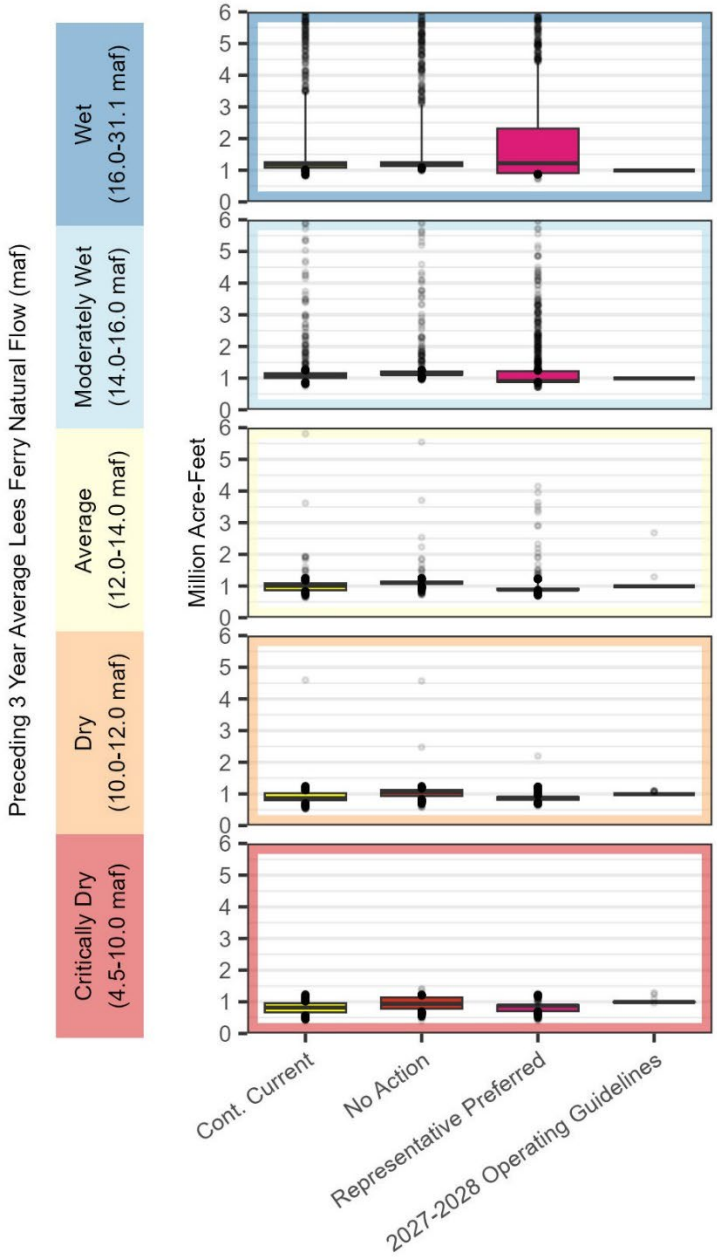
Reach 7: Northerly International Boundary in the Limitrophe to Southerly International Boundary
This reach of the river, beginning at the NIB, is divided into two sub reaches. Approximately 1.1-miles downstream from the NIB is Moreles Dam, where, under normal operations, the remaining Colorado River flow is diverted into Mexico's Reforma Canal for water supply.

Downstream of Morelos Diversion Dam, the reach continues to the SIB and the Colorado River Delta. Flows in this reach, referred to as the limitrophe, consist of water in excess of Mexico's scheduled delivery. Excess flows may result from flood control operations at Hoover Dam, seepage from Morelos Diversion Dam, irrigation return flows, groundwater inflows, or water released for environmental purposes in the Colorado River Delta.

Figure T-14 presents conditional boxplots of annual flow volume below Morelos Diversion Dam. The range of volumes is truncated to facilitate comparisons between alternatives, se**e Table T-18** at the end of this appendix for the full statistical summary.

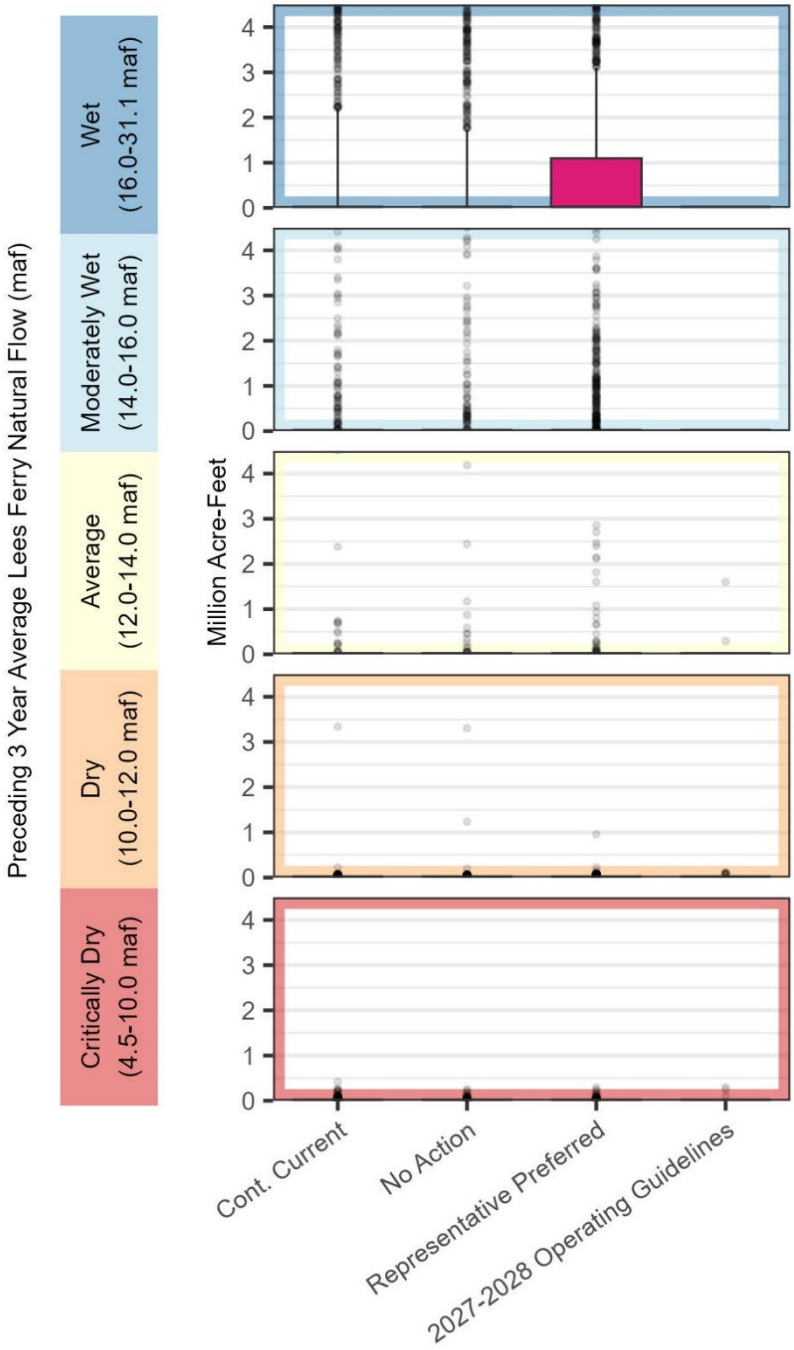
The 2027-2028 Operating Guidelines result in median annual flow volume below Morelos Diversion Dam of 0.0 maf in all flow categories. Although annual flows below Morelos Diversion Dam are infrequent in the two-year period coved by the 2027-2028 Operating Guidelines, flows in the limitrophe can exceed 10 maf (see **Table T-18**) when they do occur. These are the result of exceptionally high intervening flows included in some of the hydrologic futures included in the modeling analysis. Overall, the annual flow volume below Morelos Diversion Dam under the 2027–2028 Operating Guidelines falls within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-13
Annual Flow Volume Below Imperial Dam[10]



[10] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-17** for the full range of the data.

Figure T-14
Annual Flow Volume Below Morelos Diversion Dam[11]



[11] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table T-18** for the full range of the data.

Groundwater

Regional scale changes to groundwater are complex and hard to quantify without extensive data records and groundwater models. Current data on groundwater at a regional scale is limited in scope and historical duration.

There are no legal requirements to not deplete groundwater for nearby wells, although decreasing reservoir elevations may contribute to decreased groundwater elevations depending on hydraulic connectivity. Secondary impacts on groundwater are not considered in this analysis (e.g., if actions under the various alternatives would result in more groundwater pumping occurring in order to supplement decreased supply). See **TA 3**, Hydrologic Resources, *Issue 5: Groundwater*, for a discussion of impacts.

T.3.3 Water Deliveries

Impact Analysis Area

The geographic scope of the water deliveries analysis is the Colorado River corridor from the upstream limit of full pool elevation of Lake Powell to the downstream limit of the Southerly International Boundary. The geographic scope of this EIS does not extend above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users. Although some of the alternatives include assumptions about Upper Basin conservation, they do not specify where conserved water is generated or the specific activities used to create those conservation volumes (see **Appendix B**, Modeling Assumptions, for more information).

Impact Indicators

This section discusses impacts on the Lower Division States' water deliveries, deliveries to Mexico, and the distribution of shortages within the Lower Division States. To quantify impacts, the following indicators are used:

- Magnitude of shortage volumes
- Distribution of shortages and depletions among the Lower Division States

Lower Division States Water Supply Determinations

This section evaluates the effects of operational activities on water deliveries to the Lower Division States and Mexico by comparing the 2027–2028 Operating Guidelines, CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative using the following metrics:

- Annual Lower Basin Reductions (Shortage and Lake Mead Dead Pool–Related Reductions)
- Annual Lower Basin Shortage
- Annual Shortage by State (Arizona, California, Nevada) and water delivery reductions to Mexico
- Annual Depletions by State (Arizona, California, Nevada) and Mexico
- Surplus

Shortages & Dead Pool–Related Reductions

Shortage refers to delivery reductions at the Basin, state, or individual apportionment level that are defined and distributed as part of an alternative's shortage operations. Volumes and distributions of shortage are described in **Chapter 2,** Description of Alternatives. Dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. In some cases, these unplanned reductions occur because Lake Mead is approaching dead pool (elevation 895 feet) and in some cases they occur higher (up to elevation 950 feet).

The approach to distributing unplanned reductions associated with dead pool is not a component of any alternative. Although itis important for the impact analysis to show the volumes of these reductions, it is not appropriate to evaluate their effects on specific states or users. Accordingly, the results included beyond this section focus on shortages only. Any impacts associated with dead pool–related reductions are specifically noted.

Annual Lower Basin Reductions

Figure T-15 shows annual Lower Basin shortages and dead pool–related reductions for each alternative using conditional boxplots. The boxplots show how the alternatives perform under varying hydrologic conditions, defined by the preceding three-year average of Lees Ferry natural flow. The bottom and top of each box captures the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and outliers are shown as dots. To enable easier comparison of all flow categories, the vertical axes may have been truncated at the high end and some outliers in the Critically Dry Flow Category may have been omitted. Statistical summaries of the left and right columns are provided in **Table T-19** and **Table T-20** at the end of this appendix.

Under the 2027–2028 Operating Guidelines, an annual shortage of 1.25 maf is distributed among the Lower Division States. For this analysis, an assumed reduction to Mexico increases the total annual Lower Basin shortage to 1.5 maf. Accordingly, as shown in **Figure T-15**, the 2027–2028 Operating Guidelines result in a fixed annual Lower Basin shortage of 1.5 maf across all flow categories. This shortage falls within the range of outcomes evaluated for the Representative Preferred Alternative, which has annual shortages ranging from 0 to 3.6 maf.

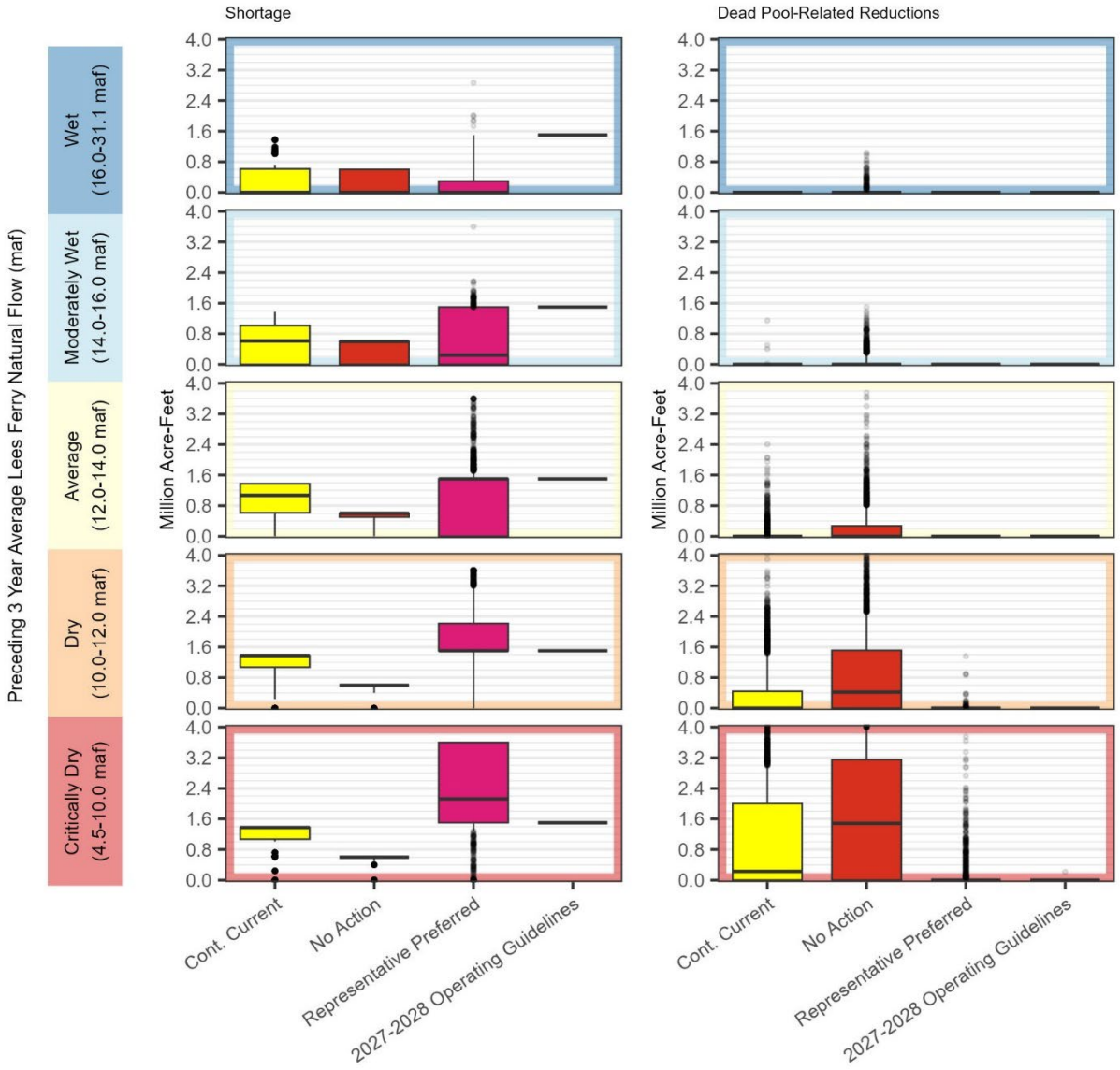
In general, smaller maximum shortage volumes correspond to more frequent and larger dead pool–related reductions, seen most prominently in the No Action Alternative. Dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. As shown in **Figure T-15**, the 2027–2028 Operating Guidelines result in relatively small dead pool–related reductions. This primarily reflects the short two-year analysis period and the initial reservoir conditions, rather than indicating that a 1.5 maf shortage is sufficient to avoid dead pool–related reductions under longer-term conditions.

In the Average Flow Category, neither the 2027–2028 Operating Guidelines nor the Representative Preferred Alternative results in dead pool–related reductions. In the Dry Flow Category, the 2027–2028 Operating Guidelines result in no dead pool–related reductions, whereas the Representative Preferred Alternative has a median dead pool–related reduction of zero and a maximum reduction

of 1.4 maf. This reflects the influence of the 2027 initial reservoir conditions rather than a significant distinction in performance (see **Section T.3.1**, Methodology) In the Critically Dry Flow Category, the Representative Preferred Alternative has a median dead pool–related reduction of zero and a maximum reduction of 3.8 maf, compared with a maximum reduction of 0.2 maf under the 2027–2028 Operating Guidelines.

Overall, impacts under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-15
Annual Lower Basin Reductions



Note: Shortage and dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions

Annual Lower Basin Shortage

Figure T-16 shows shortages to each Lower Basin State and Mexico using four columns of conditional boxplots. The vertical axis for each state's column is scaled based on its respective volume of apportionment or allotment; the percent apportionment is shown on the left side of each column, and the absolute volume of shortage is shown on the right. Statistical summaries of the data are provided in **Table T-21** through **Table T-24** at the end of this appendix.

As shown in **Figure T-16**, the 2027–2028 Operating Guidelines result in an Arizona shortage of 760 kaf, or 27.1 percent of Arizona's apportionment, in each flow category. This shortage is lower than the Representative Preferred Alternative median shortage in the Average, Dry, and Critically Dry Flow Categories. In the Average Flow Category, the Representative Preferred Alternative has a median shortage of 41.7 percent of Arizona's apportionment and a maximum of 68.3 percent. In the Dry Flow Category, the median remains at 41.7 percent, while the maximum increases to 70.2 percent. In the Critically Dry Flow Category, the median increases to 53.1 percent, the maximum remains at 70.2 percent, all of which exceed the shortage under the 2027–2028 Operating Guidelines.

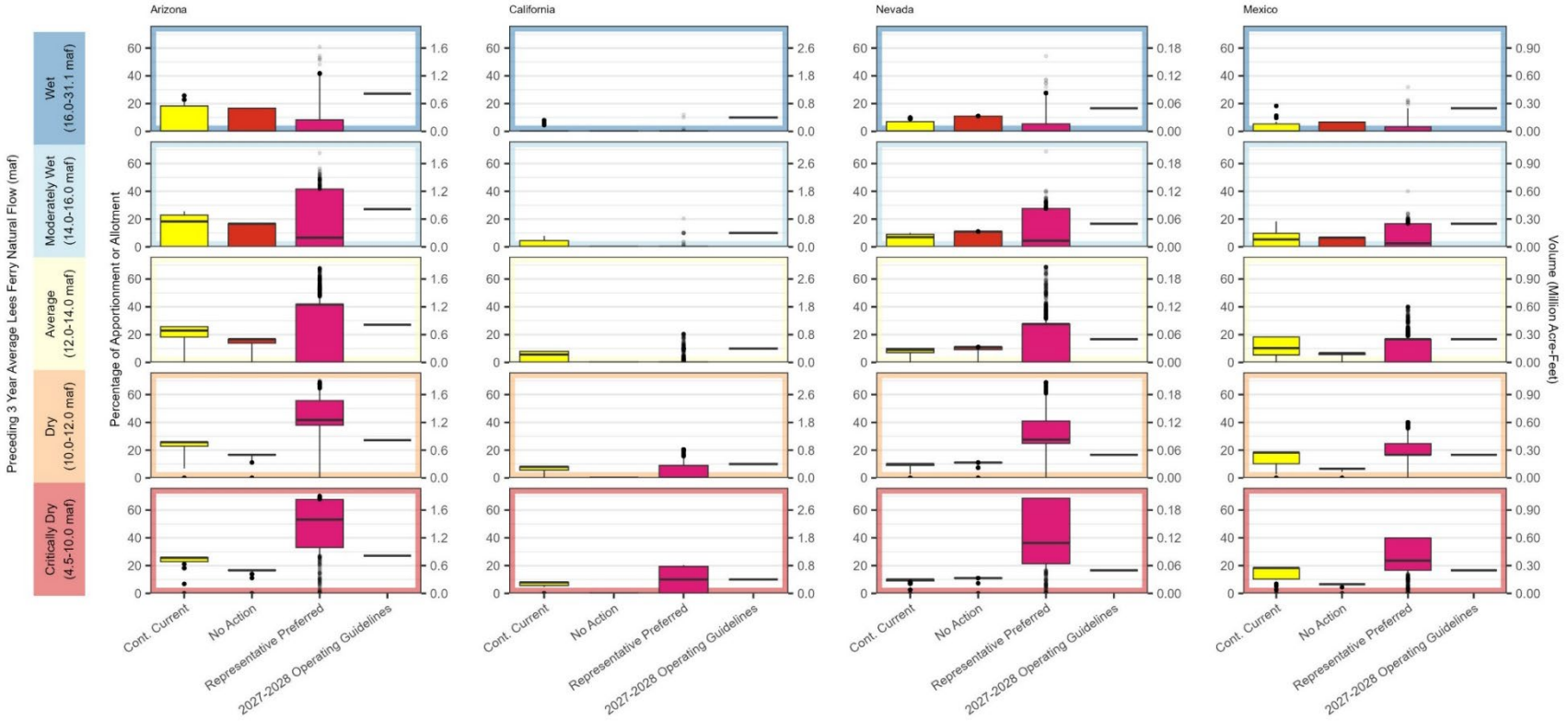
The 2027–2028 Operating Guidelines result in a California shortage of 440 kaf, or 10.0 percent of California's apportionment, in each flow category. This shortage exceeds the Representative Preferred Alternative median shortage in the Average and Dry Flow Categories and is equal to the median shortage in the Critically Dry Flow Category. In the Average Flow Category, the Representative Preferred Alternative has a median shortage of 0 percent of California's apportionment and a maximum of 20.5 percent. In the Dry Flow Category, the median remains at 0 percent and the maximum remains at 20.5 percent, with the shortage under the 2027–2028 Operating Guidelines exceeding the median but remaining below the maximum. In the Critically Dry Flow Category, the median increases to 10.0 percent of California's apportionment, equal to the shortage under the 2027–2028 Operating Guidelines, while the maximum remains at 20.5 percent.

For Nevada, the 2027–2028 Operating Guidelines result in a shortage of 50 kaf, or 16.7 percent of Nevada's apportionment, in each flow category. This shortage is lower than the Representative Preferred Alternative median shortage in the Average, Dry, and Critically Dry Flow Categories. In both the Average and Dry Flow Categories, the Representative Preferred Alternative has a median shortage of 27.6 percent of Nevada's apportionment and maximum of 68.7 percent. In the Critically Dry Flow Category, the median increases to 36.3 percent, the maximum remains at 68.7 percent, all of which exceed the shortage under the 2027–2028 Operating Guidelines.

For purposes of this analysis, the 2027–2028 Operating Guidelines are evaluated assuming a reduction to Mexico of 250 kaf, or approximately 16.67 percent of Mexico's allotment. This reduction is equal to the Representative Preferred Alternative median reduction in the Average and Dry Flow Categories and lower than the median reduction in the Critically Dry Flow Category. In both the Average and Dry Flow Categories, the Representative Preferred Alternative has a median reduction of 16.67 percent of Mexico's allotment and a maximum of 40.0 percent. In the Critically Dry Flow Category, the median increases to 23.6 percent, the maximum remains at 40.0 percent, all of which exceed the reduction under the 2027–2028 Operating Guidelines.

Overall, impacts under the 2027–2028 Operating Guidelines fall within the range of impacts evaluated for the Representative Preferred Alternative.

Figure T-16
CY Shortage by State and Water Delivery Reductions to Mexico



Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Depletions

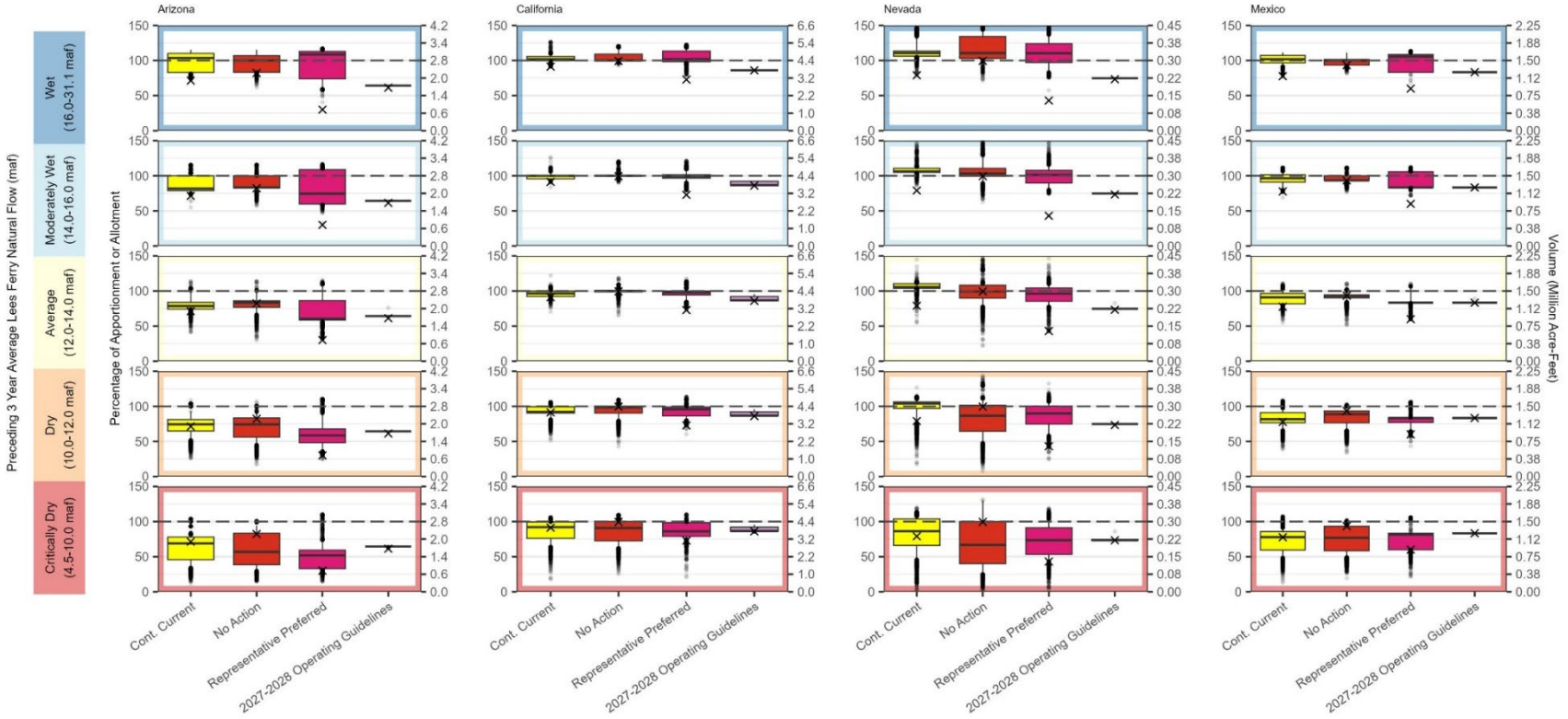
This section compares annual depletions for the Lower Division States and Mexico under the 2027–2028 Operating Guidelines, the Representative Preferred Alternative, the No Action Alternative, and the CCS Comparative Baseline. Depletion (also referred to as total consumptive use) is the net amount of water used and is calculated as the amount of water diverted from the river minus the return flow. Return flow is the portion of diverted water that is not consumed and returns to the river for subsequent downstream use. Depletions are influenced by the total shortage volume, the approach used to distribute shortages among the Lower Division States and Mexico, and modeling assumptions related to voluntary conservation mechanisms. Dead pool–related reductions are reflected in the depletion results presented in this section.

Figure T-17 shows annual depletions for each Lower Basin State and Mexico using four columns of conditional boxplots. Results are presented as both a percentage of apportionment or allotment (left axis) and a depletion volume (right axis). Unless otherwise noted, results are described in terms of percentage of apportionment or allotment. A dashed line at 100 percent of apportionment or allotment is included in each panel for reference. Each alternative also includes an "X" marker indicating the smallest depletion volume unaffected by dead pool–related reductions from Lake Mead; data points below the marker reflect depletions affected by infrastructure constraints at Lake Mead elevations near dead pool. The depletion volume associated with the marker differs among alternatives because shortage volumes vary, affecting the occurrence and magnitude of dead pool–related reductions. Statistical summaries of the data are provided in **Table T-25** through **Table T-28** at the end of this appendix.

Note, for the 2027–2028 Operating Guidelines, variability in depletions across flow categories reflects modeling assumptions related to Lake Mead storage and the delivery of conserved water rather than differences in shortage volumes (there is no variation in shortage volumes for 2027-2028 Operating Guidelines, as described in **Section T.2.1** and shown in **Figure T-16**). See **Attachment T1** for additional information on modeling assumptions specific to the 2027–2028 Operating Guidelines.

As shown in **Figure T-17**, the 2027–2028 Operating Guidelines result in Arizona depletions of approximately 1,802 kaf, or approximately 64.4 percent of Arizona's apportionment, in each flow category. This depletion exceeds the Representative Preferred Alternative median depletion in the Average and Dry Flow Categories and falls within the range of Representative Preferred Alternative outcomes in the Critically Dry Flow Category. In the Average Flow Category, the Representative Preferred Alternative has a median depletion of 60.4 percent of Arizona's apportionment and a maximum of 115.9 percent. In the Dry Flow Category, the median decreases to 58.5 percent, while the maximum decreases to 111.3 percent. In the Critically Dry Flow Category, the median decreases to 51.8 percent, the maximum decreases to 110.0 percent. The 2027–2028 Operating Guidelines depletions fall within the range of Representative Preferred Alternative outcomes.

Figure T-17
Annual Lower Basin Depletions



The 2027–2028 Operating Guidelines result in California depletions of approximately 3,810 kaf, or approximately 86.6 percent of California's apportionment, in each flow category. This depletion is lower than the Representative Preferred Alternative median depletion in the Average and Dry Flow Categories and falls between the median and maximum in the Critically Dry Flow Category. In the Average Flow Category, the Representative Preferred Alternative has a median depletion of 98.3 percent of California's apportionment and a maximum of 117.5 percent. In the Dry Flow Category, the median decreases to 95.8 percent, while the maximum decreases to 113.4 percent. In the Critically Dry Flow Category, the median decreases to 86.0 percent, the maximum decreases to 109.8 percent, with the 2027–2028 Operating Guidelines depletions falling within this range.

For Nevada, the 2027–2028 Operating Guidelines result in depletions of approximately 224 kaf, or approximately 74.7 percent of Nevada's apportionment. This depletion is lower than the Representative Preferred Alternative median depletion in the Average and Dry Flow Categories. In the Average Flow Category, the Representative Preferred Alternative has a median depletion of 96.1 percent of Nevada's apportionment and a maximum of 146.5 percent. In the Dry Flow Category, the median decreases to 89.7 percent, while the maximum decreases to 132.4 percent. In the Critically Dry Flow Category, the median depletion decreases to 73.3 percent—equal to the 2027–2028 Operating Guidelines median depletion—while the maximum decreases to 119.0 percent, placing the 2027–2028 Operating Guidelines depletions within the range Representative Preferred Alternative outcomes.

For purposes of this analysis, the 2027–2028 Operating Guidelines are evaluated assuming an annual reduction to Mexico of 250 kaf, resulting in annual depletions of approximately 1,250 kaf, or approximately 83.3 percent of Mexico's allotment. In the Average Flow Category, the Representative Preferred Alternative has a median depletion of 83.3 percent of Mexico's allotment and a maximum of 110.6 percent. In the Dry Flow Category, the median remains at 83.3 percent, while the maximum decreases to 106.5 percent. In the Critically Dry Flow Category, the median decreases to 81.5 percent, the maximum decreases to 105.6 percent. The 2027–2028 Operating Guidelines median depletion is equal to the Representative Preferred Alternative median depletion in the Average and Dry Flow Categories and exceeds the median but remains below the maximum in the Critically Dry Flow Category.

Overall, depletions under the 2027–2028 Operating Guidelines fall within the range of Representative Preferred Alternative outcomes.

Surplus

As noted in **Section T.2.1**, the 2027–2028 Operating Guidelines require consultation regarding reduced shortage volumes or the availability of Surplus when the EOCY Lake Mead elevation is projected to exceed 1,145 feet. For this analysis, the maximum EOCY Lake Mead elevation in 2027 is approximately 1,106 feet, which is below the 1,145-foot threshold. Although modeled EOCY elevations in 2028 exceed 1,145 feet **(Figure T-4)**, any resulting Surplus determination would apply to 2029 and is, therefore, beyond the scope of this analysis.

See **TA 4**, Water Deliveries, for additional information on the percentage of years with Surplus deliveries for the CCS Comparative Baseline, No Action Alternative, and Representative Preferred Alternative.

T.3.4 Other Environmental Resource Areas

Impacts to other resources are expected to fall within the range shown for the Representative Preferred Alternative in the technical appendices (**Volume III**). This is because impacts to these resources are driven primarily by reservoir elevations and releases, which are similar under the 2027-2028 Operating Guidelines and the Representative Preferred Alternative, as discussed in **Section T.3.1** above.

Specifically, results for the Dry and Critically Dry Flow Categories under the Representative Preferred Alternative best represent the range of potential impacts under the 2027-2028 Operating Guidelines. Impacts in 2027 fall within the Critically Dry Flow Category because of dry Lees Ferry natural flow conditions in 2024-2026 (see **Appendix G**, CRSS Initial Conditions, **Table G-2**). Although the flow category in 2028 depends on 2027 hydrology, impacts within the Dry and Critically Dry Flow Categories are the most plausible. Achieving the Average Flow Category in 2028 would require a Lees Ferry natural flow greater than 17.9 maf to occur in 2027, which occurred only once this century (2011). The Moderately Wet Flow Category would require a Lees Ferry natural flow greater than 23.9 maf, which has occurred only once in the historical record (1984), while the Wet Flow Category would require a Lees Ferry natural flow greater than 29.9 maf, which has never occurred in the historical record.

Modeling results for the 2027-2028 Operating Guidelines also show that annual releases from Glen Canyon Dam (**Figure T-6**) and Hoover Dam (**Figure T-9**) are generally greater than those under the Representative Preferred Alternative, particularly in the Dry and Critically Dry Flow Categories, while remaining within the range of Representative Preferred Alternative outcomes. These larger releases may mitigate adverse impacts to several resources, including hydropower, air quality, socioeconomics, population and land use, and indian trust assets.

Table T-4 below summarizes how the potential environmental impacts under the 2027-2028 Operating Guidelines compare with the modeled impacts for the Representative Preferred Alternative shown in **Volume III**. The *Explanation* column provides the basis for these comparisons by relating reservoir elevations and releases under 2027-2028 Operating Guidelines to those under the Representative Preferred Alternative, as shown in in **Figure T-3** (Lake Powell pool elevation), **Figure T-4** (Lake Mead pool elevation), **Figure T-6** (Glen Canyon Dam WY releases), and **Figure T-9** (Hoover Dam CY releases), with a focus on the Dry and Critically Dry Flow Categories.

Table T-4
Potential Environmental Impacts of the 2027-2028 Operating Guidelines Compared to the Representative Preferred Alternative

Resource	Potential Environmental Impact	Explanation
Geomorphology and Sediment (TA-5)	Similar to the Representative Preferred Alternative.	Lake Powell elevations are similar between the 2027-2028 Operating Guidelines and the Representative Preferred Alternative, indicating impacts on the ability to perform High Flow Experiments are expected to be similar.
Water Quality (TA-6)	Salinity concentration below Hoover Dam could be similar to or lower than the Representative Preferred Alternative. Impacts to dissolved oxygen and temperature below Glen Canyon Dam are expected to be similar to the Representative Preferred Alternative.	Calendar year releases from Hoover Dam under the 2027-2028 Operating Guidelines tend to be larger than under the Representative Preferred Alternative. Dissolved Oxygen and temperature are heavily impacted by Lake Powell elevations, which are similar.
Air Quality (TA-7)	Shoreline dust emissions from Lake Powell and Lake Mead are expected to be similar to the Representative Preferred Alternative.	2027-2028 Operating Guidelines have similar elevations but higher releases from Glen Canyon Dam and Hoover Dam, which could result in more hydropower production, mitigating the need for ancillary power sources. Similar reservoir elevations indicate similar shoreline dust emissions.
Fish and Aquatic Resources (TA-8)	Smallmouth bass (SMB) growth rate (lambda), SMB entrainment, and temperatures below Glen Canyon Dam are expected to be similar to the Representative Preferred Alternative. Important barriers to upstream fish movement (Lake Powell elevations 3,598, 3,600, 3,666.5 feet and Lake Mead elevation 1,090 feet) are expected to be maintained except under average or wetter hydrology. Minimum monthly releases from Hoover Dam and instream flows in reaches below Hoover Dam are expected to be higher than under the Representative Preferred Alternative.	Lambda, entrainment, and temperatures are heavily influenced by reservoir elevations, which are similar to the Representative Preferred Alternative. Important fish barriers are expected to be maintained in 2027-2028 due to low initial reservoir conditions. Flows in reaches below Hoover Dam are expected to be similar or greater than under the Representative Preferred because modeled Lower Basin shortages do not exceed 1.5 maf compared to 3.6 maf in the Representative Preferred Alternative.

Resource	Potential Environmental Impact	Explanation
Vegetation (TA-9)	Impacts to vegetation at Lake Powell are expected to be similar to the Representative Preferred Alternative. Impacts in the Grand Canyon are expected to be similar, as well, but with potentially less encroachment towards the river channel. Similar or less negative impacts to vegetation at Lake Mead and in reaches below Lake Mead are expected.	Lake Powell annual releases are similar enough that variability in inflows could have a greater impact on Lake Powell vegetation, and inflows are very similar between alternatives. Less encroachment in the Grand Canyon may occur because of larger releases under the Critically Dry Flow Category compared to the Representative Preferred Alternative. Releases from Lake Mead are less variable under the 2027-2028 Operating Guidelines, which may benefit marsh and woody vegetation.
Terrestrial Wildlife (TA-10)	Same as Vegetation	Same as Vegetation
Cultural Resources (TA-11)	Impacts similar as shown for the Representative Preferred Alternative.	Reservoir elevations are similar to Representative Preferred Alternative.
Paleontological Resources (TA-12)	Impacts similar as shown for the Representative Preferred Alternative.	Reservoir elevations are similar to the Representative Preferred Alternative.
Tribal Resources (TA-13)	Impacts similar as described for the Representative Preferred Alternative, but with potentially less exposure of sites near the riverbank.	Reservoir elevations are similar to the Representative Preferred Alternative, but releases under Critically Dry and Dry Flow Categories tend to be greater than the Representative Preferred Alternative.
Recreation (TA-14)	Proportion of recreation sites open is expected to be similar. Access to boat ramps at or above 1,040 feet at Lake Mead and above 3,590 feet at Lake Powell may be limited. Boating hazards due to elevations below 1,170 feet at Lake Mead and below 3,620 feet at Lake Powell are expected. Flows above 8,000 cfs and 5,000 cfs below Glen Canyon for whitewater boating are expected to be maintained at similar or higher frequencies. compared to the Representative Preferred Alternative.	Low initial reservoir conditions result in a low proportion of recreation sites open and suggest boat ramps at or above 1,040 feet at Lake Mead and 3,590 feet at Lake Powell may not be available unless hydrologic conditions improve. Likewise, elevations above 1,170 feet at Lake Mead and 3,620 at Lake Powell are unlikely in 2027-2028. Flows below Glen Canyon are expected to be similar or higher because the 2027-2028 Operating Guidelines tend to release larger annual volumes in Dry and Critically Dry Flow Categories than the Representative Preferred Alternative.

Resource	Potential Environmental Impact	Explanation
Dams and Electrical Power Resources (TA-15)	Both Glen Canyon Dam and Hoover Dam generation and capacity could be similar or greater than what is shown for the Representative Preferred Alternative. Minimum power pool elevations of 3,490 feet at Glen Canyon Dam and 950 feet at Hoover Dam are expected to be maintained. Loss of hydropower production due to Lake Mead elevations below 1,035 feet can occur under the Dry and Critically Dry Flow Categories. Risk to infrastructure due to high reservoir elevations is unlikely.	Similar elevations but larger releases compared to the Representative Preferred Alternative could result in greater capacity and generation. Elevations below 3,490 and 950 feet occur only as the outliers in the Critically Dry category. Elevations below 1,035 feet at Lake Mead occur frequently in the Dry and Critically Dry category due to low initial conditions and a maximum shortage of 1.5 maf. High reservoir elevations only occur in the Moderately Wet and Wet Flow Categories.
Socioeconomics (TA-16)	Impacts to cropland, market value, jobs, labor income, and total economic output are the same as reported for 'Representative Preferred (2027-2028)', but only up to 1.5 maf of shortage. The economic values of angling and rafting below Glen Canyon Dam are expected to be similar or higher than the Representative Preferred Alternative.	TA-16 reports impacts to cropland, market value, jobs, labor income, and total economic output under the LB Priority distribution and 1.5 maf of shortage, consistent with the 2027-2028 Operating Guidelines. Similar elevations but larger releases may increase the projected economic value of angling and rafting.
Population and Land Use (TA-17)	Impacts similar to or less than what is shown for the Representative Preferred Alternative are expected.	2027-2028 Operating Guidelines implement a maximum shortage of 1.5 maf whereas the Representative Preferred Alternative has a maximum of 3.6 maf.
Indian Trust Assets (TA-18)	Impacts similar to or less than what is shown for the Representative Preferred Alternative are expected.	2027-2028 Operating Guidelines implement a maximum shortage of 1.5 maf whereas the Representative Preferred Alternative has a maximum of 3.6 maf.
Visual Resources (TA-19)	Height of calcium carbonate rings at Lake Powell and Lake Mead are expected to be similar to what is shown for the Representative Preferred Alternative. Cathedral in the Desert is expected to be visible and accessible.	Elevations are similar to what is shown for the Representative Preferred Alternative. Due to low initial conditions, elevations are expected below 3,550 feet in 2027-2028 unless hydrologic conditions are Average or wetter.

T.4 Summary

This analysis shows that the anticipated 2027-2028 Operating Guidelines generally have similar or higher Lake Powell and Lake Mead elevations than the Representative Preferred Alternative, particularly in the Dry and Critically Dry Flow Categories at the median and lower percentiles. Where there are differences, these mainly reflect the shorter timeframe for the 2027-2028 Operating Guidelines and the influence of the 2027 initial reservoir conditions rather than a significant distinction in performance (see **Section T.3.1**, Methodology) The analysis of Lake Powell elevations shows that the modeled Lake Powell operations in the 2027-2028 Operating Guidelines, which adjust to maintain elevation 3,510 feet, are effective at avoiding elevation 3,500 feet. Only the outliers below the 10th percentile in the Dry Flow Category and the 25th percentile and below in the Critically Dry Flow Category fall below elevation 3,500 feet.

The 2027-2028 Operating Guidelines do not model shortages above 1.5 maf, but do include 700 kaf of additional system conservation, while the Representative Preferred Alternative includes shortages up to 3.6 maf. This affects the variability in releases from Hoover Dam as well as the flows in all reaches below Hoover Dam. This variability is also reflected in the analysis of Lower Basin shortages and deliveries, which only vary due to the assumed ICS behavior. The analysis of Lake Mead elevation and the dead pool-related reductions indicates that given the expected initial conditions in 2027, the 2027-2028 Operating Guidelines are effective at protecting elevation 950 feet at Lake Mead; however, there are still some cases where Lake Mead declines below elevation 1,000 feet in the two-year period, particularly in the Critically Dry Flow Category.

For all of the analyzed impact indicators in the Hydrologic Resources and Water Deliveries, and given the expected initial conditions in 2027, the potential impacts of the 2027-2028 Operating Guidelines are within the range of potential impacts associated with the Representative Preferred Alternative. Impacts to other resources are expected to fall within the range shown for the Representative Preferred Alternative in the technical appendices. This is because impacts to these resources are driven primarily by reservoir elevations and releases, which are similar under the 2027-2028 Operating Guidelines and the Representative Preferred Alternative.

T.5 References

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Statistical Summary Tables

Table T-5
Minimum Water Year Elevation (Feet) at Lake Powell

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16-31.1	3,686	3,680	3,676	3,667	3,643	3,604	3,499
CCS Comparative Baseline	14-16	3,686	3,675	3,659	3,609	3,560	3,534	3,462
CCS Comparative Baseline	12-14	3,683	3,649	3,589	3,549	3,508	3,492	3,414
CCS Comparative Baseline	10-12	3,667	3,573	3,535	3,500	3,478	3,456	3,398
CCS Comparative Baseline	4.5-10	3,625	3,510	3,499	3,471	3,426	3,408	3,396
No Action	16-31.1	3,686	3,680	3,677	3,671	3,658	3,619	3,503
No Action	14-16	3,687	3,677	3,668	3,630	3,571	3,534	3,433
No Action	12-14	3,685	3,660	3,622	3,549	3,490	3,465	3,411
No Action	10-12	3,669	3,609	3,523	3,471	3,449	3,432	3,398
No Action	4.5-10	3,630	3,514	3,479	3,436	3,415	3,407	3,396
Representative Preferred	16-31.1	3,683	3,674	3,665	3,648	3,630	3,617	3,562
Representative Preferred	14-16	3,681	3,641	3,630	3,614	3,595	3,579	3,497
Representative Preferred	12-14	3,658	3,615	3,597	3,574	3,550	3,528	3,476
Representative Preferred	10-12	3,624	3,569	3,549	3,525	3,506	3,495	3,450
Representative Preferred	4.5-10	3,567	3,514	3,502	3,492	3,472	3,432	3,397
2027-2028 Operating Guidelines	16-31.1	3,653	3,653	3,653	3,653	3,653	3,653	3,653
2027-2028 Operating Guidelines	14-16	3,627	3,624	3,622	3,610	3,585	3,570	3,562
2027-2028 Operating Guidelines	12-14	3,625	3,600	3,588	3,577	3,563	3,551	3,537
2027-2028 Operating Guidelines	10-12	3,567	3,551	3,543	3,528	3,517	3,507	3,492
2027-2028 Operating Guidelines	4.5-10	3,532	3,510	3,508	3,505	3,500	3,494	3,440

NOTE: Elevations colored blue are above the spill avoidance elevation of 3,680 feet. Elevations colored red are below the minimum power pool elevation of 3,490 feet.

Table T-6
EOWY Elevation (Feet) at Lake Powell

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16-31.1	3,696	3,692	3,690	3,679	3,657	3,621	3,499
CCS Comparative Baseline	14-16	3,697	3,690	3,676	3,635	3,580	3,549	3,462
CCS Comparative Baseline	12-14	3,695	3,670	3,624	3,574	3,527	3,500	3,414
CCS Comparative Baseline	10-12	3,694	3,616	3,565	3,517	3,498	3,468	3,404
CCS Comparative Baseline	4.5-10	3,689	3,560	3,525	3,499	3,457	3,424	3,398
No Action	16-31.1	3,696	3,693	3,690	3,684	3,670	3,637	3,503
No Action	14-16	3,696	3,691	3,684	3,654	3,595	3,551	3,433
No Action	12-14	3,697	3,681	3,643	3,585	3,517	3,478	3,411
No Action	10-12	3,695	3,629	3,571	3,498	3,473	3,447	3,407
No Action	4.5-10	3,688	3,571	3,517	3,478	3,443	3,421	3,400
Representative Preferred	16-31.1	3,696	3,690	3,683	3,661	3,639	3,620	3,553
Representative Preferred	14-16	3,696	3,678	3,656	3,629	3,606	3,585	3,507
Representative Preferred	12-14	3,699	3,653	3,627	3,595	3,563	3,539	3,476
Representative Preferred	10-12	3,689	3,616	3,588	3,554	3,529	3,508	3,454
Representative Preferred	4.5-10	3,680	3,592	3,555	3,523	3,498	3,468	3,398
2027-2028 Operating Guidelines	16-31.1	3,690	3,690	3,690	3,690	3,690	3,690	3,690
2027-2028 Operating Guidelines	14-16	3,674	3,667	3,663	3,620	3,585	3,570	3,562
2027-2028 Operating Guidelines	12-14	3,689	3,637	3,619	3,598	3,567	3,553	3,537
2027-2028 Operating Guidelines	10-12	3,689	3,613	3,590	3,558	3,537	3,516	3,492
2027-2028 Operating Guidelines	4.5-10	3,651	3,596	3,567	3,535	3,510	3,500	3,440

NOTE: Elevations colored blue are above the spill avoidance elevation of 3,680 feet**.** Elevations colored red are below the minimum power pool elevation of 3,490 feet.

Table T-7
Minimum Calendar Year Elevation (Feet) at Lake Mead

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16-31.1	1,217	1,210	1,196	1,130	1,067	1,046	980
CCS Comparative Baseline	14-16	1,216	1,180	1,102	1,063	1,035	1,017	910
CCS Comparative Baseline	12-14	1,206	1,113	1,066	1,030	1,007	962	898
CCS Comparative Baseline	10-12	1,195	1,070	1,028	998	924	901	897
CCS Comparative Baseline	4.5-10	1,184	1,040	1,011	932	900	898	897
No Action	16-31.1	1,217	1,209	1,194	1,116	1,015	966	936
No Action	14-16	1,215	1,180	1,093	1,006	959	949	912
No Action	12-14	1,204	1,107	1,020	967	949	932	898
No Action	10-12	1,193	1,043	993	944	907	900	897
No Action	4.5-10	1,186	1,029	988	905	900	899	897
Representative Preferred	16-31.1	1,220	1,218	1,216	1,199	1,145	1,091	1,001
Representative Preferred	14-16	1,220	1,213	1,185	1,139	1,077	1,042	975
Representative Preferred	12-14	1,219	1,180	1,144	1,097	1,036	1,012	945
Representative Preferred	10-12	1,212	1,146	1,108	1,030	995	974	898
Representative Preferred	4.5-10	1,207	1,111	1,033	990	957	914	896
2027-2028 Operating Guidelines	16-31.1	1,095	1,095	1,095	1,095	1,095	1,095	1,095
2027-2028 Operating Guidelines	14-16	1,111	1,110	1,093	1,075	1,063	1,057	1,048
2027-2028 Operating Guidelines	12-14	1,096	1,076	1,065	1,056	1,050	1,043	1,035
2027-2028 Operating Guidelines	10-12	1,075	1,053	1,041	1,032	1,023	1,014	959
2027-2028 Operating Guidelines	4.5-10	1,052	1,038	1,029	1,019	1,006	987	920

NOTE: Elevations colored blue are above the spillway elevation of 1,221 feet, listed in the previous table. Elevations colored red are below the minimum power pool elevation of 950 feet.

Table T-8
End-Of-Calendar Year Elevations (Feet) at Lake Mead

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16-31.1	1,219	1,215	1,201	1,151	1,077	1,054	980
CCS Comparative Baseline	14-16	1,219	1,185	1,118	1,072	1,042	1,025	914
CCS Comparative Baseline	12-14	1,217	1,122	1,074	1,038	1,019	980	898
CCS Comparative Baseline	10-12	1,215	1,075	1,039	1,012	946	906	898
CCS Comparative Baseline	4.5-10	1,184	1,051	1,024	962	903	900	897
No Action	16-31.1	1,218	1,215	1,198	1,139	1,029	975	947
No Action	14-16	1,218	1,187	1,110	1,016	969	958	912
No Action	12-14	1,217	1,119	1,027	978	958	939	898
No Action	10-12	1,215	1,052	1,003	959	919	901	897
No Action	4.5-10	1,186	1,034	995	931	901	900	897
Representative Preferred	16-31.1	1,220	1,218	1,217	1,209	1,168	1,115	1,027
Representative Preferred	14-16	1,220	1,215	1,191	1,147	1,091	1,054	989
Representative Preferred	12-14	1,220	1,183	1,148	1,104	1,047	1,022	953
Representative Preferred	10-12	1,219	1,150	1,113	1,041	1,005	984	907
Representative Preferred	4.5-10	1,207	1,115	1,041	1,001	970	932	897
2027-2028 Operating Guidelines	16-31.1	1,145	1,145	1,145	1,145	1,145	1,145	1,145
2027-2028 Operating Guidelines	14-16	1,169	1,164	1,141	1,117	1,108	1,099	1,097
2027-2028 Operating Guidelines	12-14	1,215	1,136	1,105	1,089	1,069	1,057	1,044
2027-2028 Operating Guidelines	10-12	1,159	1,084	1,066	1,044	1,029	1,018	959
2027-2028 Operating Guidelines	4.5-10	1,106	1,056	1,039	1,025	1,010	990	920

NOTE: Elevations colored blue are above the spillway elevation of 1,221 feet, listed in the previous table. Elevations colored red are below the minimum power pool elevation of 950 feet.

Table T-9
End-Of-Water Year Combine Storage at Lake Powell and Lake Mead (% Full)

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
CCS Comparative Baseline	16-31.1	98.2	96.4	90.7	74.3	54.9	42.3	15.8
CCS Comparative Baseline	14-16	98.1	84.6	66.9	47.4	33.6	26.5	8.2
CCS Comparative Baseline	12-14	97.7	65.0	44.9	31.6	22.9	15.4	2.4
CCS Comparative Baseline	10-12	95.7	43.5	30.4	20.9	11.9	7.1	1.6
CCS Comparative Baseline	4.5-10	78.1	31.8	22.6	13.3	5.7	3.0	1.5
No Action	16-31.1	98.3	96.1	89.9	72.5	51.3	38.4	13.0
No Action	14-16	98.1	85.2	66.2	43.7	28.4	19.9	4.9
No Action	12-14	97.4	64.7	42.4	26.6	15.9	9.9	2.2
No Action	10-12	95.5	42.4	25.9	14.5	7.8	4.8	1.9
No Action	4.5-10	78.0	29.4	19.4	9.0	4.4	2.8	1.6
Representative Preferred	16-31.1	98.5	96.5	91.6	82.4	70.5	56.7	27.3
Representative Preferred	14-16	98.6	86	75.8	62.4	47.6	37.9	18.3
Representative Preferred	12-14	97.8	71.5	57.9	45.9	33.6	26.2	10.1
Representative Preferred	10-12	94.8	54.8	43.5	31.5	22.3	17.4	6.9
Representative Preferred	4.5-10	74.5	41.5	30.7	20.8	14.1	8.3	1.4
2027-2028 Operating Guidelines	16-31.1	75.3	75.3	75.3	75.3	75.3	75.3	75.3
2027-2028 Operating Guidelines	14-16	73.6	72.3	69.1	51.3	44.1	39.9	38.5
2027-2028 Operating Guidelines	12-14	95.4	57.4	50.1	42.9	34.3	30.8	28.2
2027-2028 Operating Guidelines	10-12	76.1	43.6	37.2	30.3	25.0	22.4	13.4
2027-2028 Operating Guidelines	4.5-10	54.3	36.7	29.5	24.4	20.1	17.4	8.1

Table T-10
Water Year Releases from Glen Canyon Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	38.09	14.79	11.63	9.00	8.23	8.23	6.45
CCS Comparative Baseline	14-16	24.28	10.81	9.00	9.00	8.23	7.48	6.00
CCS Comparative Baseline	12-14	28.14	9.00	9.00	8.23	7.48	6.89	5.36
CCS Comparative Baseline	10-12	17.22	9.16	8.23	7.48	6.37	6.00	4.15
CCS Comparative Baseline	4.5-10	9.50	9.00	7.66	6.41	5.73	4.79	2.42
No Action	16-31.1	38.13	15.25	11.82	8.40	8.23	8.23	6.27
No Action	14-16	24.50	11.35	8.23	8.23	8.23	8.23	6.15
No Action	12-14	28.49	8.23	8.23	8.23	8.23	7.20	5.11
No Action	10-12	18.89	8.23	8.23	8.23	6.49	5.93	4.06
No Action	4.5-10	8.32	8.23	8.23	6.36	5.33	4.58	2.76
Representative Preferred	16-31.1	38.29	14.47	12.00	12.00	10.70	9.05	8.23
Representative Preferred	14-16	22.85	11.36	9.94	8.23	8.23	8.23	6.97
Representative Preferred	12-14	28.46	8.23	8.23	8.23	8.23	7.50	5.00
Representative Preferred	10-12	18.97	8.23	8.19	7.20	6.47	6.00	5.00
Representative Preferred	4.5-10	8.23	6.65	6.00	6.00	5.45	5.00	2.42
2027-2028 Operating Guidelines	16-31.1	12.66	12.66	12.66	12.66	12.66	12.66	12.66
2027-2028 Operating Guidelines	14-16	12.00	12.00	12.00	12.00	11.82	11.39	10.77
2027-2028 Operating Guidelines	12-14	26.01	12.00	11.11	10.07	8.82	8.48	8.23
2027-2028 Operating Guidelines	10-12	17.36	9.54	8.58	8.00	7.15	7.00	6.00
2027-2028 Operating Guidelines	4.5-10	10.83	7.12	7.00	6.83	6.23	5.88	5.00

NOTE: Releases colored blue highlight Glen Canyon Dam's median release of 8.23 maf. Releases colored red are at or below the smallest releases allowable of 4.73 maf in accordance with LTEMP (Reclamation 2016).

Table T-11
10-Year Releases from Glen Canyon Dam

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	174.0	119.6	106.6	93.0	83.3	79.4	60.4
CCS Comparative Baseline	14-16	154.5	102.8	90.4	83.5	79.5	76.3	58.6
CCS Comparative Baseline	12-14	145.4	92.2	85.4	80.4	77.3	72.0	48.2
CCS Comparative Baseline	10-12	134.5	86.7	80.9	77.7	71.4	64.0	46.3
CCS Comparative Baseline	4.5-10	132.9	83.5	79.5	74.5	65.2	56.4	38.5
No Action	16-31.1	174.6	120.6	107.8	93.3	82.3	77.8	58.8
No Action	14-16	156.8	103.8	91.0	82.3	79.2	74.6	59.4
No Action	12-14	145.5	92.3	82.3	80.8	77.0	70.7	48.7
No Action	10-12	135.3	84.7	82.0	77.8	70.4	63.5	46.3
No Action	4.5-10	135.3	82.3	80.6	74.2	64.2	55.8	40.4
Representative Preferred	16-31.1	175.7	123.5	110.8	97.7	85.2	78.4	58.8
Representative Preferred	14-16	160.9	107.8	96.6	84.4	77.0	72.8	58.0
Representative Preferred	12-14	152.3	98.2	87.6	78.8	74.0	69.0	47.8
Representative Preferred	10-12	139.6	90.0	80.4	74.8	69.2	63.1	45.1
Representative Preferred	4.5-10	133.4	84.5	78.5	72.5	64.4	56.5	40.0
2027-2028 Operating Guidelines	16-31.1	85.5	85.5	85.5	85.5	85.5	85.5	85.5
2027-2028 Operating Guidelines	14-16	82.7	82.7	82.4	82.2	81.8	81.5	81.1
2027-2028 Operating Guidelines	12-14	96.0	81.5	80.5	79.3	78.3	77.8	77.2
2027-2028 Operating Guidelines	10-12	86.4	78.5	77.6	77.0	76.1	75.8	74.9
2027-2028 Operating Guidelines	4.5-10	81.8	78.0	78.0	77.6	75.6	74.3	72.5

Table T-12
Cumulative 10-Year Lee Ferry Flow Volume (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	175.7	121.3	108.2	94.6	84.9	80.9	62.0
CCS Comparative Baseline	14-16	156.2	104.4	92.1	85.1	81.1	77.9	60.3
CCS Comparative Baseline	12-14	147.0	93.8	87.0	81.9	78.8	73.6	49.8
CCS Comparative Baseline	10-12	136.2	88.3	82.5	79.1	73.0	65.6	47.9
CCS Comparative Baseline	4.5-10	134.6	85.1	81.0	76.0	66.8	58.0	40.1
No Action	16-31.1	176.3	122.2	109.5	95.0	83.9	79.4	60.4
No Action	14-16	158.5	105.4	92.7	83.9	80.5	76.3	61.1
No Action	12-14	147.2	94.0	84.0	82.3	78.6	72.3	50.3
No Action	10-12	137.0	86.4	83.6	79.3	72.0	65.2	47.9
No Action	4.5-10	137.0	84.0	82.0	75.7	65.8	57.4	42.0
Representative Preferred	16-31.1	177.4	125.2	112.5	99.3	86.7	79.9	60.4
Representative Preferred	14-16	162.6	109.4	98.2	86.0	78.6	74.3	59.7
Representative Preferred	12-14	154.0	99.9	89.3	80.4	75.5	70.6	49.4
Representative Preferred	10-12	141.2	91.6	82.1	76.4	70.7	64.7	46.7
Representative Preferred	4.5-10	135.1	86.1	79.9	73.9	66.0	58.1	41.6
2027-2028 Operating Guidelines	16-31.1	86.7	86.7	86.7	86.7	86.7	86.7	86.7
2027-2028 Operating Guidelines	14-16	83.9	83.9	83.7	83.4	83.1	82.7	82.3
2027-2028 Operating Guidelines	12-14	97.2	82.7	81.7	80.5	79.5	79.0	78.5
2027-2028 Operating Guidelines	10-12	87.6	79.7	78.8	78.2	77.3	77.0	76.1
2027-2028 Operating Guidelines	4.5-10	83.1	79.3	79.2	78.8	76.9	75.6	73.7

Table T-13
Calendar Year Releases from Hoover Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	37.9	12.1	10.0	9.4	8.7	8.4	6.9
CCS Comparative Baseline	14-16	22.3	9.7	9.2	8.7	8.3	8.0	6.2
CCS Comparative Baseline	12-14	21.3	9.3	8.8	8.3	8.0	7.6	5.8
CCS Comparative Baseline	10-12	13.2	8.9	8.4	7.9	7.3	6.5	4.3
CCS Comparative Baseline	4.5-10	10.4	8.7	8.3	7.5	6.1	5.1	2.6
No Action	16-31.1	37.8	12.1	10.1	9.3	8.8	8.5	7.2
No Action	14-16	22.4	9.5	9.2	8.8	8.5	8.3	7.1
No Action	12-14	22.7	9.3	8.9	8.6	8.3	7.9	5.2
No Action	10-12	13.3	9.2	8.7	8.1	7.3	6.5	3.7
No Action	4.5-10	10.2	9.2	8.7	7.2	5.8	5.0	2.9
Representative Preferred	16-31.1	38.2	13.0	11.3	9.8	8.3	7.7	5.8
Representative Preferred	14-16	22.1	10.1	9.4	8.3	7.8	7.4	5.6
Representative Preferred	12-14	20.1	9.4	8.5	7.9	7.6	7.1	4.9
Representative Preferred	10-12	10.6	8.6	8.0	7.6	6.8	6.1	4.1
Representative Preferred	4.5-10	10.3	8.2	7.8	6.9	5.9	5.5	2.6
2027-2028 Operating Guidelines	16-31.1	7.6	7.6	7.6	7.6	7.6	7.6	7.6
2027-2028 Operating Guidelines	14-16	7.8	7.8	7.7	7.3	7.1	6.5	6.1
2027-2028 Operating Guidelines	12-14	9.8	8.2	7.8	7.5	7.1	6.5	6.0
2027-2028 Operating Guidelines	10-12	8.7	8.0	7.8	7.6	7.3	6.8	6.1
2027-2028 Operating Guidelines	4.5-10	8.7	8.0	7.8	7.6	7.3	7.0	5.8

Table T-14
Calendar Year Releases from Davis Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	37.6	12.1	9.9	9.3	8.6	8.3	7.1
CCS Comparative Baseline	14-16	22.5	9.6	9.1	8.6	8.2	7.9	6.4
CCS Comparative Baseline	12-14	21.9	9.2	8.7	8.2	7.8	7.6	5.7
CCS Comparative Baseline	10-12	13.3	8.8	8.3	7.9	7.2	6.5	4.3
CCS Comparative Baseline	4.5-10	10.1	8.6	8.2	7.4	6.0	5.0	2.5
No Action	16-31.1	37.5	12.1	10.0	9.2	8.7	8.4	7.6
No Action	14-16	22.6	9.4	9.1	8.7	8.4	8.2	7.3
No Action	12-14	23.2	9.2	8.8	8.5	8.2	7.8	5.2
No Action	10-12	13.4	9.0	8.7	8.1	7.2	6.3	3.7
No Action	4.5-10	9.9	9.1	8.6	7.1	5.7	4.9	2.8
Representative Preferred	16-31.1	37.9	13.1	11.2	9.7	8.1	7.6	6.0
Representative Preferred	14-16	22.2	9.9	9.3	8.2	7.6	7.4	5.7
Representative Preferred	12-14	20.6	9.3	8.4	7.8	7.5	7.0	5.2
Representative Preferred	10-12	10.5	8.5	7.9	7.5	6.8	6.0	4.5
Representative Preferred	4.5-10	10.1	8.0	7.6	6.9	5.8	5.5	2.5
2027-2028 Operating Guidelines	16-31.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3
2027-2028 Operating Guidelines	14-16	8.0	7.8	7.7	7.3	7.2	6.7	6.2
2027-2028 Operating Guidelines	12-14	9.9	8.0	7.6	7.4	7.2	6.7	6.2
2027-2028 Operating Guidelines	10-12	8.4	7.9	7.7	7.5	7.3	6.9	6.5
2027-2028 Operating Guidelines	4.5-10	8.4	7.9	7.7	7.5	7.3	7.0	6.1

Table T-15
Calendar Year Releases from Parker Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	34.8	9.2	7.0	6.7	6.5	6.4	5.9
CCS Comparative Baseline	14-16	19.9	6.9	6.7	6.6	6.4	6.3	5.8
CCS Comparative Baseline	12-14	18.7	6.8	6.6	6.5	6.3	6.2	4.8
CCS Comparative Baseline	10-12	10.6	6.7	6.5	6.3	6.1	5.6	3.6
CCS Comparative Baseline	4.5-10	7.2	6.6	6.3	6.1	5.2	4.4	2.0
No Action	16-31.1	34.4	8.8	7.0	6.8	6.6	6.5	6.1
No Action	14-16	19.6	7.0	6.8	6.6	6.5	6.4	5.8
No Action	12-14	19.7	6.8	6.7	6.6	6.4	6.3	4.4
No Action	10-12	10.6	6.8	6.6	6.4	6.0	5.3	3.2
No Action	4.5-10	7.3	6.7	6.5	6.0	4.9	4.3	2.4
Representative Preferred	16-31.1	34.8	10.0	8.0	6.8	6.5	6.2	5.7
Representative Preferred	14-16	18.8	7.0	6.7	6.5	6.3	6.1	5.1
Representative Preferred	12-14	17.4	6.7	6.5	6.4	6.2	6.0	4.9
Representative Preferred	10-12	7.9	6.6	6.4	6.2	5.9	5.5	4.1
Representative Preferred	4.5-10	7.2	6.4	6.3	5.9	5.3	5.0	2.1
2027-2028 Operating Guidelines	16-31.1	6.2	6.2	6.2	6.2	6.2	6.2	6.2
2027-2028 Operating Guidelines	14-16	6.3	6.1	5.9	5.9	5.7	5.6	5.5
2027-2028 Operating Guidelines	12-14	8.1	6.3	6.0	5.9	5.8	5.7	5.6
2027-2028 Operating Guidelines	10-12	6.3	6.2	6.1	5.9	5.8	5.7	5.5
2027-2028 Operating Guidelines	4.5-10	6.6	6.2	6.0	5.9	5.8	5.7	5.5

Table T-16
Annual Flow Volume at Imperial Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	33.5	8.1	5.8	5.6	5.5	5.5	5.2
CCS Comparative Baseline	14-16	19.1	5.7	5.6	5.5	5.4	5.3	4.8
CCS Comparative Baseline	12-14	17.3	5.6	5.6	5.5	5.3	5.3	4.0
CCS Comparative Baseline	10-12	9.2	5.6	5.5	5.3	5.2	4.6	2.8
CCS Comparative Baseline	4.5-10	5.8	5.5	5.3	5.2	4.3	3.6	1.3
No Action	16-31.1	33.1	7.8	5.8	5.7	5.6	5.5	5.1
No Action	14-16	18.7	5.7	5.7	5.6	5.5	5.5	5.0
No Action	12-14	18.2	5.7	5.6	5.6	5.5	5.3	3.7
No Action	10-12	9.2	5.6	5.6	5.5	5.0	4.4	2.4
No Action	4.5-10	5.8	5.6	5.5	5.0	4.1	3.5	1.5
Representative Preferred	16-31.1	33.5	9.0	6.9	5.7	5.4	5.3	4.8
Representative Preferred	14-16	17.4	5.9	5.7	5.4	5.3	5.2	4.2
Representative Preferred	12-14	15.9	5.7	5.4	5.3	5.3	5.1	4.0
Representative Preferred	10-12	6.5	5.5	5.4	5.3	5.0	4.5	3.3
Representative Preferred	4.5-10	5.9	5.4	5.3	5.0	4.2	4.1	1.4
2027-2028 Operating Guidelines	16-31.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0
2027-2028 Operating Guidelines	14-16	5.0	5.0	5.0	5.0	5.0	5.0	5.0
2027-2028 Operating Guidelines	12-14	6.8	5.0	5.0	5.0	5.0	5.0	5.0
2027-2028 Operating Guidelines	10-12	5.1	5.0	5.0	5.0	5.0	5.0	5.0
2027-2028 Operating Guidelines	4.5-10	5.3	5.0	5.0	5.0	5.0	5.0	5.0

Table T-17
Annual Flow Volume Below Imperial Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	28.7	3.5	1.3	1.2	1.1	1.0	0.8
CCS Comparative Baseline	14-16	14.3	1.2	1.2	1.1	1.0	0.9	0.7
CCS Comparative Baseline	12-14	12.6	1.2	1.1	1.0	0.9	0.8	0.6
CCS Comparative Baseline	10-12	4.6	1.1	1.0	0.9	0.8	0.7	0.5
CCS Comparative Baseline	4.5-10	1.2	1.0	1.0	0.8	0.7	0.6	0.4
No Action	16-31.1	28.2	3.1	1.3	1.2	1.1	1.1	1.0
No Action	14-16	13.9	1.2	1.2	1.1	1.1	1.1	0.9
No Action	12-14	13.5	1.2	1.1	1.1	1.1	1.0	0.7
No Action	10-12	4.6	1.2	1.1	1.1	0.9	0.8	0.6
No Action	4.5-10	1.4	1.2	1.1	0.9	0.8	0.7	0.4
Representative Preferred	16-31.1	28.6	4.4	2.3	1.2	0.9	0.9	0.7
Representative Preferred	14-16	12.6	1.2	1.2	0.9	0.9	0.9	0.7
Representative Preferred	12-14	11.4	1.2	0.9	0.9	0.9	0.9	0.7
Representative Preferred	10-12	2.2	0.9	0.9	0.9	0.8	0.7	0.6
Representative Preferred	4.5-10	1.3	1.0	0.9	0.9	0.7	0.7	0.4
2027-2028 Operating Guidelines	16-31.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2027-2028 Operating Guidelines	14-16	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2027-2028 Operating Guidelines	12-14	2.7	1.0	1.0	1.0	1.0	1.0	1.0
2027-2028 Operating Guidelines	10-12	1.1	1.0	1.0	1.0	1.0	1.0	1.0
2027-2028 Operating Guidelines	4.5-10	1.3	1.0	1.0	1.0	1.0	1.0	1.0

Table T-18
Annual Flow Volume Below Morelos Diversion Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	27.4	2.2	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	13.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	11.3	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	3.3	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	4.5-10	0.4	0.0	0.0	0.0	0.0	0.0	0.0
No Action	16-31.1	26.9	1.7	0.0	0.0	0.0	0.0	0.0
No Action	14-16	12.5	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	12.2	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	3.3	0.0	0.0	0.0	0.0	0.0	0.0
No Action	4.5-10	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	16-31.1	27.3	3.1	1.1	0.0	0.0	0.0	0.0
Representative Preferred	14-16	11.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	10.2	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	4.5-10	0.3	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	16-31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	12-14	1.6	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	10-12	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	4.5-10	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Table T-19
Lower Basin Shortage (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	1.4	0.7	0.6	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	1.4	1.4	1.0	0.6	0.0	0.0	0.0
CCS Comparative Baseline	12-14	1.4	1.4	1.4	1.1	0.6	0.0	0.0
CCS Comparative Baseline	10-12	1.4	1.4	1.4	1.4	1.1	0.2	0.0
CCS Comparative Baseline	4.5-10	1.4	1.4	1.4	1.4	1.1	1.0	0.0
No Action	16-31.1	0.6	0.6	0.6	0.0	0.0	0.0	0.0
No Action	14-16	0.6	0.6	0.6	0.6	0.0	0.0	0.0
No Action	12-14	0.6	0.6	0.6	0.6	0.5	0.0	0.0
No Action	10-12	0.6	0.6	0.6	0.6	0.6	0.4	0.0
No Action	4.5-10	0.6	0.6	0.6	0.6	0.6	0.5	0.0
Representative Preferred	16-31.1	2.9	1.5	0.3	0.0	0.0	0.0	0.0
Representative Preferred	14-16	3.6	1.5	1.5	0.2	0.0	0.0	0.0
Representative Preferred	12-14	3.6	1.7	1.5	1.5	0.0	0.0	0.0
Representative Preferred	10-12	3.6	3.2	2.2	1.5	1.5	0.0	0.0
Representative Preferred	4.5-10	3.6	3.6	3.6	2.1	1.5	1.3	0.0
2027-2028 Operating Guidelines	16-31.1	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2027-2028 Operating Guidelines	14-16	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2027-2028 Operating Guidelines	12-14	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2027-2028 Operating Guidelines	10-12	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2027-2028 Operating Guidelines	4.5-10	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Table T-20
Lower Basin Dead Pool–Related Reductions (maf)[12]

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16-31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	1.1	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	2.4	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	4.0	1.4	0.4	0.0	0.0	0.0	0.0
CCS Comparative Baseline	4.5-10	6.2	3.0	2.0	0.2	0.0	0.0	0.0
No Action	16-31.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	1.5	0.3	0.0	0.0	0.0	0.0	0.0
No Action	12-14	3.8	0.8	0.3	0.0	0.0	0.0	0.0
No Action	10-12	5.5	2.5	1.5	0.4	0.0	0.0	0.0
No Action	4.5-10	6.5	4.0	3.1	1.5	0.0	0.0	0.0
Representative Preferred	16-31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	4.5-10	3.8	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	16-31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	4.5-10	0.2	0.0	0.0	0.0	0.0	0.0	0.0

Note: Dead pool-related delivery reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[12] Dead pool–related reductions are in addition to shortages specified in each alternative. Shortages are shown in **Table T-19**.

Table T-21
Total State Shortage for Arizona (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	25.7	21.1	18.3	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	25.7	25.7	22.9	18.3	0.0	0.0	0.0
CCS Comparative Baseline	12-14	25.7	25.7	25.7	22.9	18.3	0.0	0.0
CCS Comparative Baseline	10-12	25.7	25.7	25.7	25.7	22.9	6.9	0.0
CCS Comparative Baseline	4.5-10	25.7	25.7	25.7	25.7	22.9	22.9	0.0
No Action	16-31.1	16.7	16.7	16.7	0.0	0.0	0.0	0.0
No Action	14-16	16.7	16.7	16.7	16.7	0.0	0.0	0.0
No Action	12-14	16.7	16.7	16.7	16.7	13.9	0.0	0.0
No Action	10-12	16.7	16.7	16.7	16.7	16.7	11.1	0.0
No Action	4.5-10	16.7	16.7	16.7	16.7	16.7	13.9	0.0
Representative Preferred	16-31.1	60.9	41.7	8.2	0.0	0.0	0.0	0.0
Representative Preferred	14-16	67.6	41.7	41.7	6.7	0.0	0.0	0.0
Representative Preferred	12-14	68.3	47.3	41.7	41.7	0.0	0.0	0.0
Representative Preferred	10-12	70.2	64.5	55.6	41.7	38.0	0.0	0.0
Representative Preferred	4.5-10	70.2	67.6	67.6	53.1	33.1	27.1	0.0
2027-2028 Operating Guidelines	16-31.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1
2027-2028 Operating Guidelines	14-16	27.1	27.1	27.1	27.1	27.1	27.1	27.1
2027-2028 Operating Guidelines	12-14	27.1	27.1	27.1	27.1	27.1	27.1	27.1
2027-2028 Operating Guidelines	10-12	27.1	27.1	27.1	27.1	27.1	27.1	27.1
2027-2028 Operating Guidelines	4.5-10	27.1	27.1	27.1	27.1	27.1	27.1	27.1

Table T-22
Total State Shortage for California (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	8.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	8.0	8.0	4.5	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	8.0	8.0	8.0	5.7	0.0	0.0	0.0
CCS Comparative Baseline	10-12	8.0	8.0	8.0	8.0	5.7	0.0	0.0
CCS Comparative Baseline	4.5-10	8.0	8.0	8.0	8.0	5.7	4.5	0.0
No Action	16-31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	4.5-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	16-31.1	11.9	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	20.5	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	20.5	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	20.5	15.3	8.9	0.0	0.0	0.0	0.0
Representative Preferred	4.5-10	20.5	20.5	19.5	10.0	0.0	0.0	0.0
2027-2028 Operating Guidelines	16-31.1	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2027-2028 Operating Guidelines	14-16	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2027-2028 Operating Guidelines	12-14	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2027-2028 Operating Guidelines	10-12	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2027-2028 Operating Guidelines	4.5-10	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Table T-23
Total State Shortage for Nevada (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	10.0	8.3	7.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	10.0	10.0	9.0	7.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	10.0	10.0	10.0	9.0	7.0	0.0	0.0
CCS Comparative Baseline	10-12	10.0	10.0	10.0	10.0	9.0	2.7	0.0
CCS Comparative Baseline	4.5-10	10.0	10.0	10.0	10.0	9.0	9.0	0.0
No Action	16-31.1	11.0	11.0	11.0	0.0	0.0	0.0	0.0
No Action	14-16	11.0	11.0	11.0	11.0	0.0	0.0	0.0
No Action	12-14	11.0	11.0	11.0	11.0	9.2	0.0	0.0
No Action	10-12	11.0	11.0	11.0	11.0	11.0	7.4	0.0
No Action	4.5-10	11.0	11.0	11.0	11.0	11.0	9.2	0.0
Representative Preferred	16-31.1	54.2	27.6	5.4	0.0	0.0	0.0	0.0
Representative Preferred	14-16	68.7	27.6	27.6	4.4	0.0	0.0	0.0
Representative Preferred	12-14	68.7	31.3	27.6	27.6	0.0	0.0	0.0
Representative Preferred	10-12	68.7	60.6	41.0	27.6	24.9	0.0	0.0
Representative Preferred	4.5-10	68.7	68.7	68.5	36.3	21.4	16.7	0.0
2027-2028 Operating Guidelines	16-31.1	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	14-16	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	12-14	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	10-12	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	4.5-10	16.7	16.7	16.7	16.7	16.7	16.7	16.7

Table T-24
Water Delivery Reductions to Mexico (Percent of Allotment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	18.3	6.9	5.3	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	18.3	18.3	9.7	5.3	0.0	0.0	0.0
CCS Comparative Baseline	12-14	18.3	18.3	18.3	10.3	5.3	0.0	0.0
CCS Comparative Baseline	10-12	18.3	18.3	18.3	18.3	10.3	2.7	0.0
CCS Comparative Baseline	4.5-10	18.3	18.3	18.3	18.3	10.3	9.7	0.0
No Action	16-31.1	6.7	6.7	6.7	0.0	0.0	0.0	0.0
No Action	14-16	6.7	6.7	6.7	6.7	0.0	0.0	0.0
No Action	12-14	6.7	6.7	6.7	6.7	5.6	0.0	0.0
No Action	10-12	6.7	6.7	6.7	6.7	6.7	4.4	0.0
No Action	4.5-10	6.7	6.7	6.7	6.7	6.7	5.6	0.0
Representative Preferred	16-31.1	31.9	16.7	3.3	0.0	0.0	0.0	0.0
Representative Preferred	14-16	40.0	16.7	16.7	2.7	0.0	0.0	0.0
Representative Preferred	12-14	40.0	18.9	16.7	16.7	0.0	0.0	0.0
Representative Preferred	10-12	40.0	35.6	24.6	16.7	16.7	0.0	0.0
Representative Preferred	4.5-10	40.0	40.0	40.0	23.6	16.7	14.3	0.0
2027-2028 Operating Guidelines	16-31.1	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	14-16	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	12-14	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	10-12	16.7	16.7	16.7	16.7	16.7	16.7	16.7
2027-2028 Operating Guidelines	4.5-10	16.7	16.7	16.7	16.7	16.7	16.7	16.7

Table T-25
Annual Arizona Depletions (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	115.3	115.3	110.0	103.5	83.0	81.1	73.3
CCS Comparative Baseline	14-16	115.3	103.5	100.0	81.7	78.8	74.3	55.0
CCS Comparative Baseline	12-14	113.9	100.0	83.9	78.7	74.3	73.7	41.3
CCS Comparative Baseline	10-12	108.6	93.1	81.1	74.3	64.8	51.9	26.2
CCS Comparative Baseline	4.5-10	103.5	81.6	78.0	68.8	45.7	34.4	11.4
No Action	16-31.1	115.3	115.3	106.8	100.0	83.3	82.9	61.7
No Action	14-16	115.3	100.0	100.0	83.3	82.8	76.7	56.9
No Action	12-14	113.7	100.0	86.0	83.3	76.9	66.3	29.9
No Action	10-12	106.6	91.9	83.3	74.2	56.2	45.0	17.9
No Action	4.5-10	101.6	94.2	83.3	56.7	38.7	29.6	15.3
Representative Preferred	16-31.1	116.8	115.3	112.9	108.6	73.8	59.5	40.6
Representative Preferred	14-16	116.7	110.0	108.6	74.4	59.8	58.5	32.4
Representative Preferred	12-14	115.9	108.6	86.4	60.4	58.5	56.7	31.7
Representative Preferred	10-12	111.3	89.9	67.7	58.5	48.2	35.9	24.5
Representative Preferred	4.5-10	110.0	73.0	59.3	51.8	32.9	31.0	14.9
2027-2028 Operating Guidelines	16-31.1	64.4	64.4	64.4	64.4	64.4	64.4	64.4
2027-2028 Operating Guidelines	14-16	64.4	64.4	64.4	64.4	64.4	64.4	64.4
2027-2028 Operating Guidelines	12-14	76.1	64.4	64.4	64.4	64.4	64.4	64.4
2027-2028 Operating Guidelines	10-12	64.4	64.4	64.4	64.4	64.4	64.4	64.4
2027-2028 Operating Guidelines	4.5-10	64.4	64.4	64.4	64.4	64.4	64.4	61.3

Table T-26
Annual California Depletions (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	126.3	110.0	105.6	101.9	100.0	99.2	91.9
CCS Comparative Baseline	14-16	125.8	105.6	100.3	100.0	95.8	92.0	83.8
CCS Comparative Baseline	12-14	122.0	101.1	100.0	96.6	92.0	92.0	70.6
CCS Comparative Baseline	10-12	105.6	100.0	99.4	92.0	90.3	81.3	51.4
CCS Comparative Baseline	4.5-10	105.6	100.0	99.4	92.0	76.1	64.2	17.8
No Action	16-31.1	120.2	118.8	109.1	100.0	100.0	100.0	92.8
No Action	14-16	120.2	100.6	100.0	100.0	100.0	98.8	89.8
No Action	12-14	118.7	100.0	100.0	100.0	99.0	96.0	65.7
No Action	10-12	109.1	100.0	100.0	98.4	90.3	79.5	42.9
No Action	4.5-10	109.1	100.6	100.0	90.9	72.5	62.3	25.5
Representative Preferred	16-31.1	122.7	118.6	113.4	101.9	98.3	96.6	80.0
Representative Preferred	14-16	121.5	109.7	101.4	98.9	96.6	90.3	78.8
Representative Preferred	12-14	117.5	103.0	100.0	98.3	94.5	84.8	73.5
Representative Preferred	10-12	113.4	100.0	98.9	95.8	86.1	79.9	60.3
Representative Preferred	4.5-10	109.8	99.8	98.3	86.0	78.9	74.7	20.8
2027-2028 Operating Guidelines	16-31.1	86.1	86.1	86.1	86.1	86.1	86.1	86.1
2027-2028 Operating Guidelines	14-16	92.0	92.0	92.0	86.6	86.1	86.1	86.1
2027-2028 Operating Guidelines	12-14	95.7	95.7	92.0	86.6	86.1	86.1	86.1
2027-2028 Operating Guidelines	10-12	95.7	95.7	92.0	86.6	86.1	86.1	86.1
2027-2028 Operating Guidelines	4.5-10	95.7	95.7	92.0	86.6	86.1	86.1	86.0

Table T-27
Annual Nevada Depletions (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	146.8	133.3	113.5	110.5	106.2	104.8	79.0
CCS Comparative Baseline	14-16	145.9	112.6	110.5	106.2	104.8	103.8	85.8
CCS Comparative Baseline	12-14	145.0	110.7	110.5	105.8	103.8	103.8	54.7
CCS Comparative Baseline	10-12	126.7	110.5	106.2	103.8	96.8	76.9	17.4
CCS Comparative Baseline	4.5-10	120.2	106.8	103.8	86.3	66.1	46.0	2.8
No Action	16-31.1	210.5	143.8	134.1	110.5	103.1	99.5	71.3
No Action	14-16	186.6	129.7	110.5	103.1	99.5	89.5	62.8
No Action	12-14	201.3	110.5	108.3	99.5	90.0	77.8	22.2
No Action	10-12	172.9	110.5	101.3	86.5	64.5	47.7	7.9
No Action	4.5-10	131.6	129.7	99.9	66.8	40.2	24.9	2.7
Representative Preferred	16-31.1	158.5	136.2	123.9	110.4	97.2	83.7	57.5
Representative Preferred	14-16	150.2	115.3	107.8	101.4	89.7	80.4	43.0
Representative Preferred	12-14	146.5	110.2	104.2	96.1	85.5	77.3	43.0
Representative Preferred	10-12	132.4	106.6	100.5	89.7	74.7	58.3	24.8
Representative Preferred	4.5-10	119.0	103.3	91.2	73.3	53.1	43.0	2.8
2027-2028 Operating Guidelines	16-31.1	74.7	74.7	74.7	74.7	74.7	74.7	74.7
2027-2028 Operating Guidelines	14-16	74.7	74.7	74.7	74.7	74.7	74.7	74.7
2027-2028 Operating Guidelines	12-14	82.7	74.7	74.7	74.7	74.7	74.7	74.7
2027-2028 Operating Guidelines	10-12	74.7	74.7	74.7	74.7	74.7	74.7	74.7
2027-2028 Operating Guidelines	4.5-10	86.0	74.7	74.7	73.3	73.3	73.3	73.3

Table T-28
Annual Mexico Depletions (Percent of Allotment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	16-31.1	111.2	111.2	107.1	101.8	96.5	91.5	77.7
CCS Comparative Baseline	14-16	111.2	106.1	101.3	96.5	91.0	81.7	68.9
CCS Comparative Baseline	12-14	111.2	101.8	96.5	91.0	81.7	80.2	55.0
CCS Comparative Baseline	10-12	108.8	96.5	91.0	81.7	76.6	65.8	38.4
CCS Comparative Baseline	4.5-10	107.1	91.0	85.7	77.7	59.5	48.6	12.7
No Action	16-31.1	111.2	111.2	101.7	100.0	93.3	93.3	81.8
No Action	14-16	111.2	101.7	100.0	93.3	93.3	90.0	76.7
No Action	12-14	111.2	100.0	94.4	93.3	90.3	84.3	51.6
No Action	10-12	103.6	95.6	93.3	88.7	76.5	65.5	34.2
No Action	4.5-10	101.7	94.4	93.3	76.8	58.4	49.1	19.4
Representative Preferred	16-31.1	113.3	111.2	108.3	105.6	83.3	83.3	68.1
Representative Preferred	14-16	112.3	105.6	105.6	83.3	83.3	83.3	60.0
Representative Preferred	12-14	110.6	105.6	83.3	83.3	83.3	82.7	60.0
Representative Preferred	10-12	106.5	83.3	83.3	83.3	76.9	64.4	43.5
Representative Preferred	4.5-10	105.6	83.3	83.3	81.5	60.0	59.5	21.3
2027-2028 Operating Guidelines	16-31.1	83.3	83.3	83.3	83.3	83.3	83.3	83.3
2027-2028 Operating Guidelines	14-16	83.3	83.3	83.3	83.3	83.3	83.3	83.3
2027-2028 Operating Guidelines	12-14	89.2	83.3	83.3	83.3	83.3	83.3	83.3
2027-2028 Operating Guidelines	10-12	83.3	83.3	83.3	83.3	83.3	83.3	83.3
2027-2028 Operating Guidelines	4.5-10	83.3	83.3	83.3	83.3	83.3	83.3	80.9

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State

Attachment T1

Modeling Assumptions for Anticipated Operating Guidelines for 2027-2028

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Attachment T1. Modeling Assumptions for Anticipated Operating Guidelines for 2027-2028

As of the date of this Final EIS, the anticipated guidelines for the first operating interval (2027 and 2028) are still being refined. These anticipated guidelines are based on extensive engagement with the Basin States and incorporate tribal input. For the purpose of this attachment, these anticipated guidelines are referred to as "2027-2028 Operating Guidelines."

The Colorado River Simulation System (CRSS) model is used to simulate operations of the major reservoirs on the Colorado River system for the 2027-2028 Operating Guidelines. This attachment includes detailed modeling assumptions used for the 2027–2028 Operating Guidelines, which are described in **Appendix T, Section T.2**. For additional information on the CRSS model background, overview, hydrology inputs, and initial reservoir conditions, see **Appendix A**, CRSS Modeling Assumptions.

T1.1 Operations Upstream of Lake Powell

The operations of the Upper Basin reservoirs upstream of Lake Powell for the 2027-2028 Operating Guidelines are the same as other alternatives as described in **Appendix A**, CRSS Modeling Assumptions, except as noted below for Powell Infrastructure Protection (PIP) releases when additional releases from CRSP Upper Initial Units are needed to protect critical infrastructure at Glen Canyon Dam.

T1.1.1 Powell Infrastructure Protection Releases

Section T.2.4, Releases to Protect Glen Canyon Dam, describes the additional releases from the CRSP Upper Initial Units to protect critical infrastructure at Glen Canyon Dam. The following sections detail the modeling representation of that description for the 2027-2028 Operating Guidelines. For the remainder of this attachment, these are referred to as PIP releases.

PIP releases are modeled as releases from Upper Initial Units under low elevation conditions at Lake Powell in the 2027-2028 Operating Guidelines. The PIP release modeling assumptions are simplifications of the actual PIP process, which, like the Drought Response Operations Agreement (DROA), involves collaborative decision-making among stakeholder workgroups and includes subjective judgments that cannot be captured in a model. The modeled PIP releases represent a potential range of releases; actual releases may be lower, higher, or may not occur, and do not reflect the views of all stakeholders. These modeling assumptions are intended solely for NEPA analysis and do not reflect a position by Reclamation on operations that might be implemented under a PIP collaborative process.

For modeling purposes, all PIP releases are assumed to be made from Flaming Gorge Reservoir.

2027 PIP Releases and Model Initialization

For modeling purposes, Flaming Gorge Reservoir's December 31st starting elevation and May 1 target were adjusted based on the June 2026 24-Month Study (24-MS) Most Probable projection. This adjustment was made to align the model with projected 2026-2027 DROA operations year, which projects a PIP release of 1.0 maf.

Powell Trigger

PIP releases from Flaming Gorge Reservoir are assumed to occur in coordination with Lake Powell operations. PIP releases are triggered when Lake Powell water year release is reduced below 7.0 maf through a mid-year adjustment, which occurs in April. This operational adjustment is modeled to occur in April to initiate PIP releases at the start of the Flaming Gorge operating year (May – April). See **Section T1.2.2**, *Mid-Year Annual Release Adjustment*, for details.

Available Volume

The total volume from Flaming Gorge Reservoir available for a PIP release is limited to the amount of water stored above the designated lower limit elevation. A forecasting algorithm estimates the elevation for the future annual operating target month. These forecasts assume daily spring flow release patterns followed by baseflow releases under the same hydrologic conditions throughout the forecast period.

The lower limit elevation and annual operating target month for Flaming Gorge Reservoir is 5,890 feet in April (May 1), which is 19 feet above minimum power pool. Typical May 1 targets range from 6,027 to 6,023 feet depending on the hydrologic conditions.

The lower limit elevation is used to determine the available volume and the annual operational target, but there is no modeled logic to protect and/or maintain lower limit storage on a month-to-month basis. Flaming Gorge Reservoir can fall below the lower limit, which may prevent it from meeting future environmental targets.

Releases

Maximum Annual Release

For modeling purposes, the maximum annual PIP release from Flaming Gorge Reservoir is assumed to be 1.0 maf. This corresponds with the potential to reduce Lake Powell releases from 7.0 maf to 6.0 maf and the attempt to maintain a 1:1 ratio between the Lake Powell release reductions and the increased CRSP Upper Initial Unit releases (PIP release).

Distribution of Releases

The total PIP release contribution is the smaller of two values: the volume by which Lake Powell's release is reduced below 7.0 maf, or the total volume available from Flaming Gorge Reservoir. Because Flaming Gorge Reservoir is the only CRSP Upper Initial Unit modeled to make PIP releases, the full PIP release volume is assigned to it.

Flaming Gorge Reservoir Operational Adjustments

Flaming Gorge Reservoir operations are adjusted within their Records of Decision to release an additional volume equal to the assigned contribution by modifying their operating targets. The annual contribution from Flaming Gorge Reservoir is estimated at the end of each operating year.

Flaming Gorge Reservoir's May 1 target is lowered by its assigned contribution. If the reservoir did not reach its normal May 1 target in the previous year due to PIP releases, the prior May 1 elevation is adjusted by the new assigned contribution. The May 1 target elevation cannot be lower than 5,890 feet (lower limit elevation). Operations are adjusted based on the sub annual flow regime as follows:

- Spring: No changes to the spring operations are modeled. Spring operations are modeled by a daily hydrograph that ramps up from baseflow to peak and back to baseflow. Operations vary by hydrologic classification and peak timing.
- Baseflow: The release in baseflow is the greater of the steady release to achieve the May 1 target or the minimum for Reach 2 (Jensen, UT) for the hydrologic classification. The release in all baseflow months is constrained further by the minimum and maximum for Reach 1 (below Flaming Gorge Reservoir). All maximum and minimum flows are from the 2022 Drought Response Operation Plan,[1] which uses the +/- 40 percent or 25 percent flexibility in the Record of Decision and vary by season.
- Transition: Releases during the transition period in March and April are constrained to a maximum of 2,000 cfs, which is based on an operator estimate of F&WS/Recovery Program preference.[2]

Recovery

Recovery is not explicitly modeled. Instead, Flaming Gorge Reservoir is modeled to naturally recover in years without PIP releases as it returns to the normal annual operating targets.

T1.2 Lake Powell Operation

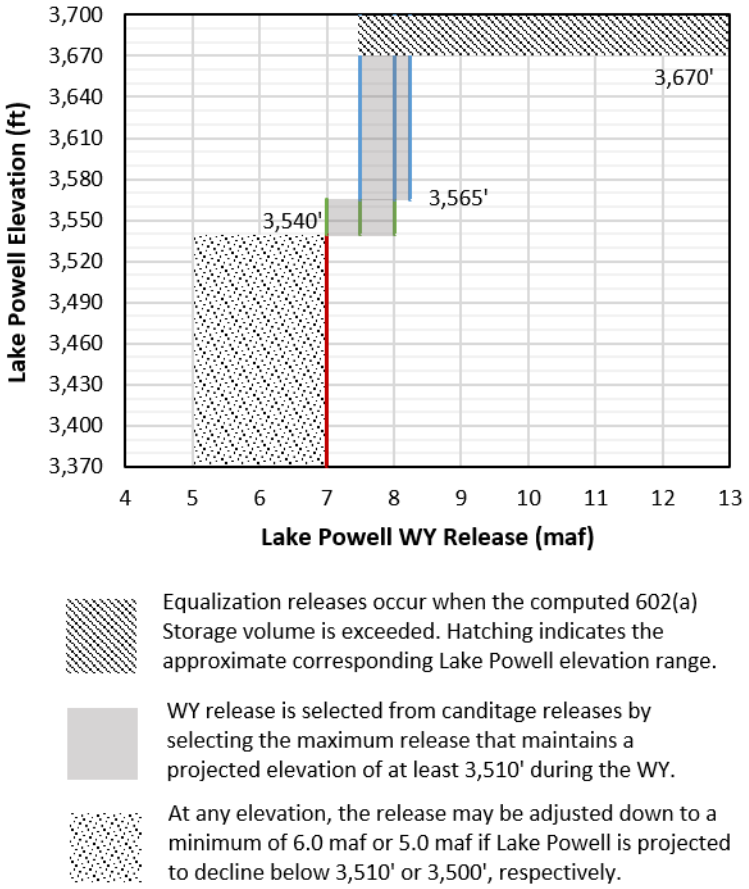
Lake Powell is the most downstream reservoir in the Upper Basin, impounded by Glen Canyon Dam near Page, Arizona. Lake Powell operates on a water year (October through September) basis with an annual release set at the beginning of the water year with possible adjustments throughout the year. Modeling assumptions common to all alternatives, including methods for disaggregating annual releases to monthly flows, safe operating capacity, and infrastructure constraints at low elevations, are summarized in **Appendix A**, CRSS Modeling Assumptions.

Under the modeled representation of the 2027–2028 Operating Guidelines, the Lake Powell water year release is established at the beginning of each water year based on the previous end of water year (EOWY) (September 30) Lake Powell pool elevation.

[1] Attachment C - Appendix 1, Estimated Normal / Maximum / Minimum Summer to Winter Baseflows in the Green River downstream from Flaming Gorge Dam, page 84-85.
[2] Typically, the transition period is the unconstrained release to achieve the May 1 target.

Figure T1-1 summarizes the Lake Powell release in the 2027-2028 Operating Guidelines. If the assumed 602(a) storage criteria are met (described in the subsequent section), Lake Powell operations are described in **Section T1.2.1**. Otherwise, Lake Powell operations are described in **Section T1.2.2**.

Figure T1-1
Coordinated Operations of Lake Powell and Lake Mead, 2027-2028 Operating Guidelines



T1.2.1 Coordination at High Elevations

If the combined Colorado River Storage Project (CRSP) storage is above the 602(a) storage volume at the previous EOWY and Lake Powell EOWY storage is greater than Lake Mead EOWY storage, equalization operations determine the water year release. A detailed description of the 602(a) storage volume calculation and parameters used in the calculation is found in **Appendix J**. For modeling purposes, the same parameters that were used to compute the 602(a) storage volume for the 2007 Interim Guidelines Equalization line are used for modeling the equalization operations in the 2027-2028 Operating Guidelines. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.

The 602(a) storage volume is not converted to a Lake Powell elevation. The water year release is set to the minimum of the volume needed to bring the CRSP storage down to the calculated 602(a)

storage volume or to balance the Lake Powell and Lake Mead projected EOWY storage, but no lower than the computed maximum release using the primary operations. The modeled 602(a) storage volume grows over time; in 2027, the volume is 25,082,344 af and in 2060 it reaches 29,647,144 af. Equalization may only be triggered at the start of the water year, and once an equalization determination is made, Lake Powell operates in the Equalization Tier for the remainder of the water year.

T1.2.2 Primary Operations

Initial Water Year Release

The initial water release is determined in October based on the September 30 Lake Powell pool elevation and a series of potential initial Lake Powell Water Year Releases as shown in **Table T1-1** and **Figure T1-1**. Before selecting an initial release, the potential releases are evaluated to identify which annual release volumes maintain a projected Lake Powell elevation of at least 3,510 feet during the following spring. For modeling purposes, and in order to evaluate the maximum impacts on Lake Powell, the initial release is determined by selecting the maximum release from the potential release volumes meeting the criterion. The next section describes the potential adjustments to this initial water year release volume during the water year in response to changing hydrologic conditions.

The corresponding monthly releases are then calculated using the method described in **Appendix A, Section A.6.1,** *Disaggregation from Annual to Monthly Release*.

Table T1-1
Potential Initial Water Year Releases by Lake Powell Pool Elevation, 2027-2028 Operating Guidelines

Lake Powell End-of-September Pool Elevation (feet)	Potential Initial Lake Powell Water Year Releases (maf)
> 3,565	8.23, 8.0, and 7.5
3,565 to 3,540	8.0, 7.5, and 7.0
< 3,540	7.0

When Lake Powell's September 30 elevation is below 3,540 feet, the modeled implementation evaluates an initial water year release of 7.0 maf. If Lake Powell is projected to remain above 3,510 feet in March, the 7.0 maf release is selected and monthly releases are calculated as described above. If Lake Powell is projected to decline below 3,510 feet in March, releases from October through March are instead set using a dynamic monthly release pattern rather than a prescribed water year release pattern deferring the determination of the water year release until April. This pattern is designed to avoid elevation 3,500 feet while respecting the Long-Term Experimental Management Plan (LTEMP) minimum daily release of 6,521 cfs. In April, the water year release is set, likely between 6.0 and 7.0 maf, contemporaneously with the modeled PIP releases to protect critical infrastructure at Glen Canyon Dam, as described in the *Mid-Year Release Adjustments* section and in **Section T1.1.1**

The projections used to evaluate the potential initial water year releases are designed to approximate the inputs that would be used in an actual 24-Month Study. In practice, the 24-Month Study relies on the current Lake Powell unregulated inflow forecast from the Colorado Basin River Forecast Center, which in August is typically close to the historical average unregulated inflow, adjusted for antecedent conditions such as soil moisture carried over from the previous year. For modeling purposes, CRSS estimates the March elevation using the historical median Lake Powell inflow (1991-2020), along with any PIP releases assigned for the current PIP year. Because CRSS does not know in advance the volume of PIP releases that will occur, a proportional PIP volume is assumed to occur between October and March for this projection. This volume is calculated by multiplying the assigned annual PIP volume by the proportion of the 2026-2027 PIP volume that was projected to occur between October and March based on the June 2026 Most Probable 24-Month Study.

Mid-Year Release Adjustments

There is potential for either an upward or a downward mid-year adjustment to the initial water year release. For modeling purposes, these adjustments occur in April. After these adjustments are made to the annual release, monthly releases are calculated using the method described in **Appendix A, Section A.6.1,** *Disaggregation from Annual to Monthly Release*.

An upward adjustment occurs if the projected EOWY Lake Powell elevation is above 3,565 feet. In this case, the initial water year release is increased by half of the projected volume above the storage corresponding to elevation 3,565 feet, up to a maximum release of 12.0 maf. This adjustment can occur with any selected initial water year release.

A downward adjustment is evaluated to reduce the risk that Lake Powell will decline below elevation 3,510 feet during the next spring. The downward adjustment can occur with any selected initial water year release. To determine whether a downward adjustment is needed, Lake Powell's projected elevation in March of the following year is evaluated. This projection assumes forecasted Lake Powell inflow (see **Appendix A, Section A.6.2**, *Lake Powell Inflow Forecast*) for the remainder of the current water year and median Lake Powell inflow (1991-2020) for the following water year. For the water year release, the selected initial release for the current water year is used (7.0 maf if in the lowest tier) followed by an assumed 7.0 maf release in the following water year using the standard monthly release pattern. No PIP release is assumed in this projection since this projection determines if a PIP release is necessary in conjunction with a reduced Lake Powell release.

If Lake Powell is projected to be above 3,510 feet in March of the following water year, the initial annual release set at the beginning of the current water year is retained, and no PIP releases are initiated. If Lake Powell is projected to be below 3,510 feet, the volume needed to maintain 3,510 feet is determined and used to adjust releases. First, the Lake Powell water year release is reduced to 7.0 maf if the initial release was greater than 7.0 maf. If additional reductions are necessary to meet the volume needed to maintain 3,510 feet, then the Lake Powell release is further reduced while PIP releases are increased. There is an attempt to maintain a 1:1 ratio between the additional Lake Powell release reductions and the PIP releases, subject to a maximum assumed PIP release of 1.0 maf and a minimum Lake Powell water year release of 6.0 maf. The subsequent section describes the potential to reduce releases below 6.0 maf.

Reduced Releases for Infrastructure Protection

Lake Powell releases can be reduced to a minimum of 6.0 maf if Lake Powell is projected to drop below 3,510 feet during the water year, and releases can be reduced to a minimum of 5.0 maf if Lake Powell is projected to drop below 3,500 feet during the water year. In CRSS, first the current month's Lake Powell pool elevation is evaluated, and then the projected EOWY Lake Powell pool elevation with an assumed 5.0 maf and 6.0 maf release for the water year is used to determine the monthly release.

- If the projected EOWY Lake Powell pool elevation with a 5.0 maf release is less than 3,500 feet, the monthly release is calculated using the method described in **Appendix A, Section A.6.1,** *Disaggregation from Annual to Monthly Release*. with an assumed the annual release of 5.0 maf.
- If the projected EOWY Lake Powell pool elevation with a 6.0 maf release is less than 3,510 feet but greater than 3,500 feet, the monthly release is calculated using the method described in **Appendix A, Section A.6.1,** *Disaggregation from Annual to Monthly Release*. with an assumed annual release of 6.0 maf.
- If the projected EOWY Lake Powell pool elevation with a 6.0 maf release is less than 3,500 feet but projected EOWY Lake Powell pool elevation with a 5.0 maf release is greater than 3,500 feet, the monthly release is calculated using the method described in **Appendix A, Section A.6.1,** *Disaggregation from Annual to Monthly Release*. assuming the annual release of the volume needed to end the water year at 3,500 feet (computed to be between 5.0 and 6.0 maf).
- If the current Lake Powell pool elevation is below 3,500 feet but the projected EOWY Lake Powell pool elevation with a 5.0 maf release is greater than 3,500 feet and the projected EOWY Lake Powell pool elevation with a 6.0 maf release is greater than 3,510 feet, the current month's release is decreased such that the Lake Powell pool elevation is maintained at or above 3,500 feet; however, it is subject to the following constraints: the minimum water year release is 5.0 maf, and the monthly release will be no less than the volume necessary to meet the minimum daily LTEMP release (6,521 cfs).

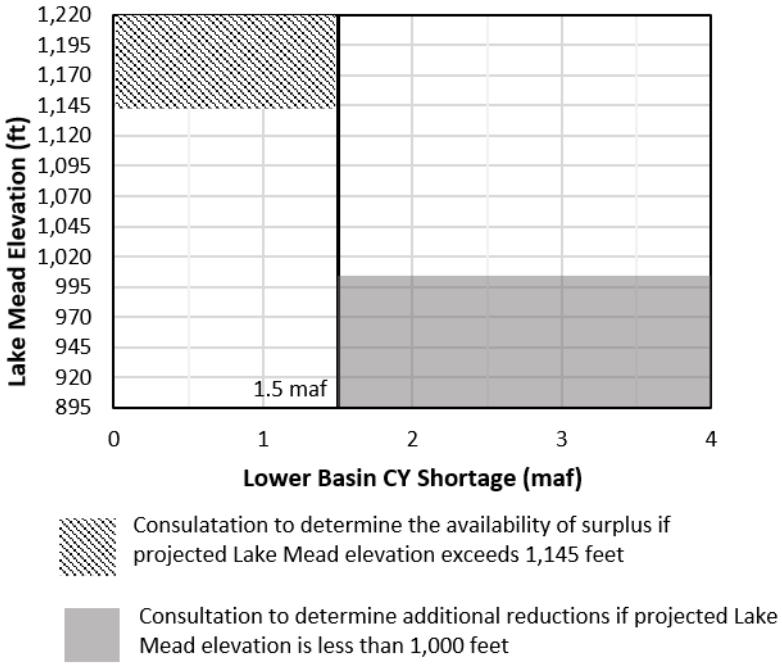
If releases are adjusted to protect 3,500 or 3,510 feet during a given month of the water year and Lake Powell pool elevation increases above 3,500 or 3,510 feet, monthly releases can be increased to release up to the original selected water year release.

T1.3 Lake Mead Operation

Lake Mead is the uppermost reservoir in the Lower Basin. In CRSS, Lake Mead operations are modeled by solving for the Lower Basin condition, Lower Basin and Mexico diversions, and the conservation, storage, and delivery of conserved system and non-system water, then setting Lake Mead's outflow to meet all downstream diversions. For detailed information on the modeling assumptions—including water user depletions, water passing to Mexico in excess of treaty requirements and water bypassed pursuant to International Boundary and Water Commission (IBWC) Minute 242, flood control operations, infrastructure constraints at low elevations, and dead pool-related reductions—see **Appendix A**, CRSS Modeling Assumptions.

Figure T1-2 summarizes the modeled Lake Mead operations in the 2027-2028 Operating Guidelines, and they are described more in the following sections.

Figure T1-2
Shortage Guidelines to Reduce Deliveries from Lake Mead, 2027-2028 Operating Guidelines



T1.3.1 Normal and Surplus Conditions

If Lake Mead is projected to exceed elevation 1,145 feet, consultation regarding reduced shortage volumes or the availability of surplus would occur. Neither normal nor surplus conditions are modeled in the analysis of the 2027-2028 Operating Guidelines.

T1.3.2 Shortage Condition

In 2027 and 2028, an annual shortage volume of 1.25 maf would be distributed among the Lower Division States, with an assumed reduction to Mexico bringing the total Lower Basin-wide shortage to 1.5 maf. This 1.5 maf shortage volume is applied in all 400 simulated futures in both 2027 and 2028. Shortages above 1.5 maf are not modeled as shown in **Figure T1-1**; however; if Lake Mead is projected to decline below elevation 1,000 feet during any 12-month period, consultation would occur to evaluate whether additional actions are necessary to reduce the risk of Lake Mead declining below elevation 950 feet. The modeled shortage volume is distributed among the Lower Division States and Mexico as shown in **Table T1-2** below. For modeling purposes only, the Arizona shortage is distributed proportionally to all Arizona Priority 4 water users; the California shortage is assumed to be applied to the Metropolitan Water District (MWD); and the Nevada shortage is assumed to be applied to the Southern Nevada Water Authority (SNWA).

Table T1-2
Shortage Distribution,
2027-2028 Operating Guidelines

Entity	Shortage (kaf)	Shortage (%)
Arizona	760	43.33
California	440	36.67
Nevada	50	3.33
Mexico	250	16.67

Note: Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

T1.4 Storage and Delivery of Conserved System Water

T1.4.1 Lake Powell Mechanism

There is no modeled Lake Powell mechanism nor is there any modeled Upper Basin conservation in the analysis of the 2027-2028 Operating Guidelines.

T1.4.2 Lake Mead Mechanism

Water conserved by Lower Basin users would be stored in a pool in Lake Mead that can reach a maximum volume of 5.3 maf, which includes the storage of pre-2027 Intentionally Created Surplus (ICS) except for System Efficiency ICS. All conserved water stored in Lake Mead would be included in determinations of equalization releases from Lake Powell and in projections of Lake Mead's elevation for consultations regarding additional/reduced Lower Basin shortage or availability of Lower Basin surplus. Lower Colorado River entitlement holders, including Lower Basin Tribes, consistent with applicable implementation agreements, would be able to contribute to the conservation pool and to use their conserved water for delivery and/or in intra- and interstate transactions with other Lower Basin users.

The subsequent sections provide a detailed description of the modeling assumptions and associated constraints. Specific assumptions for the creation and delivery of ICS in 2027 and 2028 were based on the assumptions used for the Representative Preferred Alternative (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Treatment of Pre-2027 Intentionally Created Surplus

For modeling purposes only, except for System Efficiency ICS, ICS created under the 2007 Interim Guidelines and 2019 Drought Contingency Plan (DCP) that remains in Lake Mead in 2027 is converted to the post-2026 Lake Mead mechanism on January 1, 2027.

General Assumptions

The maximum capacity of the Lake Mead mechanism, along with individual annual creation and delivery limits, is provided in **Table T1-3** below. The Lake Mead mechanism – State Pools operate on a calendar year to align with reservoir operations.

Table T1-3
Volume Limitations of Storage and Delivery of Conserved Water, 2027-2028 Operating Guidelines

Entity	Maximum Annual Contribution (kaf)	Maximum Cumulative Storage (kaf)	Maximum Annual Delivery (kaf)	Maximum Cumulative 2027 2028 Delivery (kaf)
Arizona	125	1,000	300	800
California	400	2,000	400	
Nevada	125	800	300	
Mexico[1]	250	1,500	N/A	160
Total	**900**	**5,300**	**1,160**	**960**

1) Volumes include modeling assumptions for Mexico's storage and delivery limits. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
2) There is an assumed maximum cumulative delivery to Mexico of 160 kaf for 2027–2028. No annual maximum is specified; the annual delivery is constrained only by the two-year cumulative limit of 160 kaf.

Water users could contribute or deliver water previously stored under this new mechanism at their discretion within the annual volume constraints related to the pool (**Table T1-3**). At the time the water is conserved, a one-time 10 percent system assessment is applied, followed by an annual 3 percent evaporation deduction calculated based on the volume remaining in the Lake Mead mechanism at the end of the preceding calendar year.

For modeling purposes only, additional delivery constraints include the following:

- Delivery from the Lake Mead mechanism is prohibited when Lake Mead begins the year with a physical pool elevation below 1,000 feet. When the beginning-of-year pool elevation is between 1,000 feet and 1,025 feet, delivery/conversion volumes are proportionally reduced so that the forecasted EOCY pool elevation does not fall below 1,000 feet. Note, because the constraint is based on forecasted conditions, modeled elevations may still fall below 1,000 feet.
- The cumulative delivery by the Lower Division States is limited to 800 kaf through the end of 2028. As a modeling simplification, this constraint is applied to California's 2028 delivery when applicable. Based on the delivery assumptions (described in the following sections), the constraint applies only when California receives its maximum delivery of 400 kaf in 2027. Because the other States' delivery logic does not produce maximum deliveries, any necessary reduction to stay within the 800 kaf limit was applied to California.

- Delivery of stored water from the Lake Mead mechanism is limited such that a state's annual apportionment or Mexico's annual allotment is not exceeded.
- Delivery/conversion of existing DCP ICS (Arizona) and Binational Water Scarcity Contingency Plan credits (Mexico) is allowed when Lake Mead's pool elevation exceeds 1,110 feet.

Arizona Creation and Delivery Assumptions

In general, Arizona's creation and delivery of conserved water is inversely related to the physical elevation at Lake Mead and the state shortage volume. For modeling purposes only, Arizona's conservation activity is modeled using the Central Arizona Project (CAP) and Colorado River Indian Tribe-Arizona (CRIT-AZ) water users.

Creation

Arizona is modeled to create up to 125 kaf annually, depending on the state's total shortage volume. As in the Representative Preferred Alternative, the annual creation volume is calculated as the lesser of 1,200 kaf minus Arizona's policy shortage of 760 kaf and Arizona's maximum annual creation volume of 125 kaf (**Table T1-3**). For the modeled 2027 and 2028 Operating Guidelines, the annual shortage of 760 kaf to Arizona results in a modeled annual creation of 125 kaf.

The computed state creation volume is then split to the CAP and CRIT-AZ water users using the methodology described in the Enhanced Coordination Alternative (see **Appendix B, Section B.6.2.3**, *Creation*).

Delivery

For the modeled 2027 and 2028 Operating Guidelines, Arizona is assumed to take delivery of storage credits from the Lake Mead mechanism as a modeling representation of federal tribal firming obligations,[3] with delivery volumes based on specified CAP shortage thresholds shown in **Table T1-4**. This assumption was adapted from the No Action, Enhanced Coordination, and Representative Preferred Alternatives (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Table T1-4
Storage Credit Delivery/Conversion Volumes by Shortage Threshold, 2027-2028 Operating Guidelines

Current Year Shortage for CAP (kaf)	Delivery Volume (kaf)
≥ 592	36.924
< 592 to ≥ 512	24.325

[3] Please see the Arizona Water Settlements Act, Pub. L. 108-451, 118 Stat. 3478 (Dec. 10, 2004), section 105, for a general description of the firming program. All firming deliveries in any given year would be made in accordance with applicable law. This appendix is not a legal interpretation of the firming program or of federal obligations. Actual firming deliveries may vary from the modeling approximations contained in this appendix, and Reclamation retains discretion to include legally required tribal deliveries in this priority mechanism.

As a result of the 760 kaf shortage to Arizona, Arizona is assumed to take delivery of 36.924 kaf of storage credits in both 2027 and 2028 modeled as a delivery to CAP.

California Creation and Delivery Assumptions

In general, California's creation and delivery of conserved water is based on the Sacramento River Water Year Type (SRWYT), described more in **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water. For modeling purposes, California's ICS creation and delivery is modeled using MWD.

Creation

The annual assumed creation volumes are shown below in **Table T1-5**.

Table T1-5
California's Assumed Creation Volumes,
2027-2028 Operating Guidelines

SRWYT	Total (kaf)
C	0
D	0
BN	100
AN	200
W	400

Conservation is assumed to first go towards meeting any shortages in the same year it occurs. Any remaining conserved water is stored in the Lake Mead mechanism. Because there is an assumed shortage of 460 kaf in 2027 and 2028 to California, there is no modeled creation of additional ICS in 2027 or 2028.

Delivery

The annual assumed delivery volumes are shown below in **Table T1-6**.

Table T1-6
California's Assumed Delivery Volumes,
2027-2028 Operating Guidelines

SRWYT	Total (kaf)
C	400
D	240
BN	0
AN	0
W	0

Nevada Creation and Delivery Assumptions

Creation

SNWA is modeled to store two types of water in the Lake Mead mechanism: conserved water and Tributary Conservation. With respect to Tributary Conservation, which represents conservation on the Virgin and Muddy Rivers, 35 kaf per year is created. This water is stored in the Lake Mead mechanism if space is available, after the applicable 10 percent system assessment is applied. In CRSS, this is modeled as a gain to Lake Mead.

For conserved water, SNWA's annual creation is calculated using following equation:

$$Annual\ Creation = Maximum(\ 300{,}000\ af - Annual\ Shortage_{NV} - AnnualSystemConservation_{NV} + TributaryConservation - Annual\ Demand_{NV}, 0\ af)$$

The system conservation assumptions are described in **Section T1.4.4**, and the Tributary Conservation is the volume after the system assessment is applied. Based on the assumed depletion schedules, SNWA creates ICS in 2027 and 2028 because the assumed depletions are below the state's annual apportionment in both years (see **Appendix M**, Lower Division States Depletion Schedules).

Delivery

In the Representative Preferred Alternative, Nevada's water stored in the Lake Mead mechanism is assumed to mitigate shortages; however, based on the assumed shortage volumes in the modeling of the 2027-2028 Operating Guidelines, no deliveries are necessary to mitigate shortages.

If Nevada's account in the Lake Mead mechanism is full or dead pool-related reductions occur, SNWA is assumed to take full delivery of its Tributary Conservation.

Mexico Creation and Delivery Assumptions

Reclamation developed modeling assumptions for the storage and delivery of deferred water by Mexico to evaluate possible impacts of this activity on flow and other resources for the Final EIS.[4] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In general, the volumes of creation and delivery depend on the assumed annual delivery reductions to Mexico, and the storage credits are used to mitigate these delivery reductions. The assumptions from the Supply Driven Alternative were used for this modeling, with the results of those assumptions described below.

Creation

The Supply Driven Alternative assumed Mexico would create up to 250 kaf per year, depending on its total reduction volume. Specifically, Mexico's assumed creation equals 250 kaf minus Mexico's

[4] Assuming activity in Mexico maximizes the effects on river flows as it occurs at the most downstream point in CRSS.

reduction. Because Mexico's reductions are assumed to be 250 kaf in both years of the 2027-2028 Operating Guidelines, no annual creation occurs.

Delivery

In the Supply Driven Alternative Mexico is assumed to convert storage credits to meet assumed delivery reductions that exceed 250 kaf. Because Mexico's reductions are assumed to be 250 kaf in both years of the 2027-2028 Operating Guidelines, no delivery occurs.

T1.4.3 Lake Mead Mechanism – Federally Managed Water Resources Pool

There are no model assumptions for the Federally Managed Water Resources Pool included in this analysis; however, the 2027-2028 Operating Guidelines are anticipated to include a Federally Managed Water Resources Pool. For more information on the Federally Managed Water Resources Pool, see **Chapter 2, Section 2.4.3.3.3**. The modeling of the Representative Preferred Alternative includes representative modeling of this pool.

T1.4.4 System Conservation: 700+ Plan

As described in the Lower Division States' May 1 proposal, the Lower Division States intend to contribute a cumulative minimum of 700 kaf of system conservation through 2028. Each state's contribution is assumed to be split equally between 2027 and 2028. These volumes are separate from ICS, not stored in individual state pools, and in addition to the previously described shortage volumes (**Section T1.3.2**).

Table T1-7 shows the annual system conservation volumes assumed for modeling purposes only for each state, totaling 700 kaf through 2028. The table also identifies the water user for which system conservation is modeled to occur, based on available demand and maximum downstream reach impacts.

Table T1-7
Assumed Annual System Conservation Volumes by State, 2027-2028 Operating Guidelines

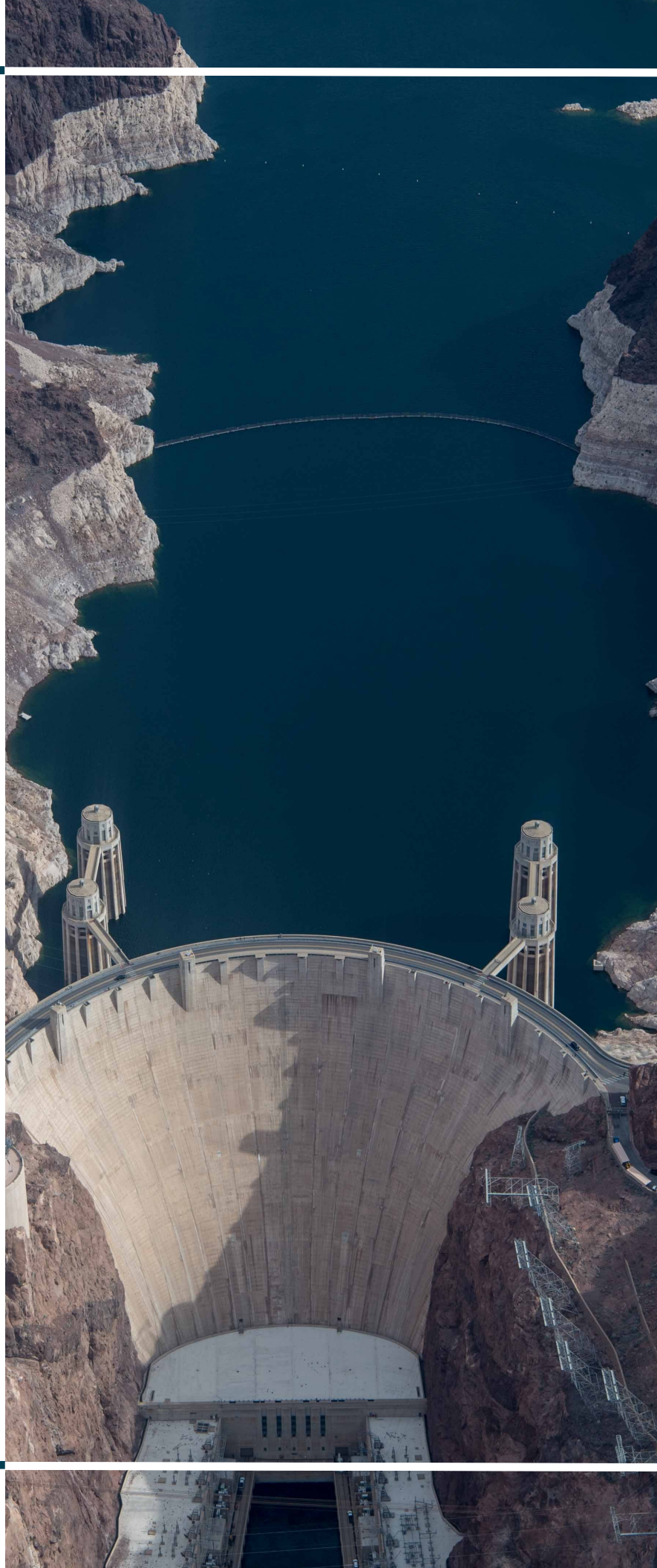
State	Water User that System Conservation is Modeled On	Annual Conservation (kaf)	Cumulative 2027-2028 Conservation (kaf)
Arizona	Wellton Mohawk Irrigation and Drainage District (IDD)	150	300
California	Imperial Irrigation District (IID)	150	300
Nevada	Southern Nevada Water Authority (SNWA)	50	100
Total		**350**	**700**

BUREAU OF
RECLAMATION

Final Environmental Impact Statement

Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead

Volume III: Resource Analysis Technical Appendices



July 2026
U.S. Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Basins
Interior Regions 7 and 8

BUREAU OF
RECLAMATION

Mission Statements

The **Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo: Alexander Stephens / Bureau of Reclamation, 2018

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Technical Appendix 3

Hydrologic Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
1944 Water Treaty	1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2007 Final EIS	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2007 ROD	2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Record of Decision
2016 LTEMP ROD	2016 Glen Canyon Dam Long-Term Experimental and Management Plan Record of Decision
2024 Final SEIS	2024 Near-term Colorado River Operations Final Supplemental Environmental Impact Statement
2024 LTEMP ROD	Supplemental Glen Canyon Dam Long-Term Experimental and Management Plan ROD
2024 ROD	2024 Near-term Colorado River Operations Record of Decision
AAC	All-American Canal
af	acre-feet
Basin	Colorado River Basin
CCS	Continued Current Strategies
CE	current era
cfs	cubic feet per second
CRSP	Colorado River Storage Project
CRSS	Colorado River Simulation System
CY	calendar year
DCP	Drought Contingency Plan
DMDU	Decision Making under Deep Uncertainty
DROA	Drought Response Operations Agreement
EIS	environmental impact statement
EOCY	end of calendar year
EOWY	end of water year
GCNP	Grand Canyon National Park
ICS	Intentionally Created Surplus

kaf	thousand acre-feet
kafy	thousand acre-feet per year
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
LROC	Long-Range Operating Criteria
maf	million acre-feet
Mexico	United Mexican States
NIB	Northerly International Boundary
Reclamation	Bureau of Reclamation
RM	river miles
ROD	Record of Decision
SEIS	Supplemental Environmental Impact Statement
SIB	Southerly International Boundary
UIU	Upper Initial Unit
Upper Basin	Upper Colorado River Basin
U.S.	United States
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WY	water year

TA 3. Hydrologic Resources

TA 3.1 Affected Environment

This section presents an overview of the hydrology of the Colorado River Basin (Basin) beginning with the full pool elevation of Lake Powell and extending downstream along the Colorado River to the Southerly International Boundary (SIB) with the United Mexican States (Mexico). It also includes groundwater that is under the direct influence of the Colorado River and the Lower Colorado River Basin (Lower Basin) reservoirs, starting with Lake Powell on the upstream end. The geography and connectivity of the hydrologic resources analysis area are the same as what was analyzed in the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (EIS; 2007 Final EIS; Reclamation 2007a).

The Colorado River has been divided into nine distinct reaches along the study area. These reaches include the full pool Lake Powell to Glen Canyon Dam, from Glen Canyon Dam to Lake Mead at Separation Canyon (which includes the Grand Canyon National Park [GCNP]), the full pool Lake Mead (downstream of Separation Canyon) to Hoover Dam, from Hoover Dam to Davis Dam (including Lake Mohave), Davis Dam to Parker Dam (including Lake Havasu), from Parker Dam to Cibola Gage, from Cibola Gage to Imperial Dam, from Imperial Dam to the Northerly International Boundary (NIB), and from the NIB to the SIB. Refer to **Table 3-1**, Colorado River Reaches and Reach Limits in the Geographic Scope, for a description of the nine Colorado River reaches and their associated river miles and **Map 3-1**, Colorado River Reaches and Geographic Scope, for a map of the Colorado River reaches. Not included in the study area are reservoirs upstream of Lake Powell, the Salton Sea, and portions of northwestern Mexico that are operated independently.

Hydrologic resources within the study area that could potentially be affected by the implementation of any given alternative include:

- Reservoir storage, total system storage, reservoir releases, and corresponding changes in Colorado River flows downstream of the reservoirs
- Groundwater in areas adjacent to and connected to the Colorado River corridor

The overall characteristics and connectivity of the Basin remain unchanged from when the 2007 Final EIS was issued. However, since 2007, several factors have affected hydrologic resources in the Basin. These factors can be divided into two categories: operational changes in the Basin since 2007 and key environmental drivers. Refer to **Chapter 1**, Purpose and Need, **Section 1.8.2.1**, The Law of the River, for a summary of operational changes since 2007.

Worsening drought conditions have been a major driver for changes to hydrologic resources in the Basin. Since 2000, the Basin has experienced persistent drought conditions, exacerbated by a

warming climate resulting in increased evapotranspiration, reduced soil moisture, and ultimately reduced runoff. Runoff conditions in the Basin are below what was contemplated in the Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 ROD) resulting in reduced reservoir storage, reservoir releases, and river flows.

TA 3.1.1 Hydrologic Overview

The Colorado River originates at the Continental Divide in Rocky Mountain National Park in Colorado and flows downstream through Utah, Nevada, Arizona, and California to Mexico, where it historically flowed into the Sea of Cortez. Major tributaries to the Colorado River include the Green, San Juan, Yampa, Gunnison, and Gila Rivers. While 85 percent of the Basin is desert and semi-arid rangelands, the remaining 15 percent is comprised of mountainous areas in Wyoming, Colorado, Utah, and New Mexico. These mountainous areas receive snow throughout the winter months, which makes up the majority, approximately 92 percent, of the Colorado River's streamflow. Mountain snowmelt in the Upper Colorado River Basin (Upper Basin) typically results in high river flows in the late spring that diminish quickly by mid-summer. The rest of the arid and semi-arid Basin historically receives fewer than 10 inches of precipitation per year. Flow in the Colorado River is highly variable from year to year because of variations in precipitation in the Basin. However, the Basin is currently experiencing a prolonged dry period resulting in extended periods of drought and record low runoff conditions.

The Colorado River Basin Climate and Hydrology: *State of the Science* report provided a comprehensive assessment of Basin hydroclimate conditions and trends through 2019 (Lukas and Payton 2020). According to the report, the Basin has experienced persistent drought conditions since 2000, exacerbated by increasing temperatures. This drought has led to a 20 percent decrease in average annual Upper Basin (at Lees Ferry Gaging Station) natural flows (Reclamation 2025a). 2000 to 2024 was the driest 25-year period in more than a century. A paleo reconstruction of Colorado River streamflow at Lee Ferry Compact Point, Arizona back to 762 current era (CE) indicates that this 24-year period is lower than any other period in the last 1,200 years (Meko et al. 2007).

These conditions have led to a cumulative streamflow deficit of about 70.0 million acre-feet (maf) relative to twentieth-century conditions (Reclamation 2025a). Historically, the primary driver for the hydrologic drought in the Basin has been below normal precipitation over the winter, resulting in reduced snowmelt in the spring, but warming temperatures are playing an increasing role as evaporative losses and soil moisture deficits increase.

Annual water use in the Basin has exceeded the annual inflows in most years since 2000. This resulted in a depletion of storage to a historic low of 24 percent of the total combined capacity of Lake Powell and Lake Mead (equivalent to approximately 12.68 maf) between March and April of 2023 (Reclamation 2025b). Since publication of the 2007 Final EIS, changes in the Basin have included further increases in temperature, ongoing years of below-normal precipitation, declining snowpack water volume and annual streamflow, and earlier snowmelt runoff. Since 2000, the average temperature across the Lower Basin has been 2.2 degrees Fahrenheit warmer than the twentieth-century average. Since 2007, the average temperature of the Lower Basin has trended upward, with the warmest 10-year period on record occurring from 2012 to 2022 (NOAA 2025).

Multidecadal trends are most informative when describing Basin precipitation due to the high interannual variability of weather events. For example, short term trends like the El Niño-Southern Oscillation can impact Lower Basin precipitation trends on a year-to-year basis. For both the Upper Basin and Lower Basin, a declining (but statistically non-significant) trend was noted over the period from 1980 to 2019. During the 1980 to 2019 period, precipitation over the cold season (October through March), which typically falls as snow, showed a greater declining trend than precipitation over the warm-season months. Because of naturally colder temperatures, snowpack at higher elevations in the Upper Basin has not been affected as much as snowpack at lower elevations; however, studies summarized in the *State of the Science* report indicate that snowmelt runoff is occurring 1–3 weeks earlier than the average timing prior to 2000.

TA 3.1.2 Upper Basin

Congress passed the Colorado River Storage Project Act in 1956, which authorized the construction of the Colorado River Storage Project (CRSP) reservoirs "to initiate the comprehensive development of the water resources of the Upper Basin, for the purposes, among others, of regulating flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for the reclamation of arid and semiarid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the foregoing purposes…"

In addition to Lake Powell, the CRSP reservoirs include the Upper Basin reservoirs, known as CRSP Upper Initial Units (UIU). The CRSP UIU are Flaming Gorge in Utah, Navajo in New Mexico, and Blue Mesa in Colorado. These four CRSP reservoirs were constructed in the 1960s and took several years to begin filling. Excluding surcharge space, the total storage volume of the four CRSP reservoirs is 29.5 maf.

Flaming Gorge Reservoir has a total storage capacity of 3.79 maf and from 1980 to the implementation of the 2007 ROD, the average storage capacity (as a percentage of the total capacity) of Flaming Gorge Reservoir was approximately 82 percent. From 2007 through 2024, the average storage capacity of Flaming Gorge Reservoir was 83 percent. Flaming Gorge Reservoir experienced the two lowest storage capacities from 2002 to 2004 and spring 2023 of 68 percent and 65 percent of the total capacity, respectively.

Navajo Reservoir has a total storage capacity of 1.71 maf and from 1980 to the implementation of the 2007 ROD, the average storage capacity (as a percentage of the total capacity) of Navajo Reservoir was approximately 80 percent. From 2007 through 2024, the average storage capacity of Navajo Reservoir was 71 percent. Navajo Reservoir experienced the two lowest storage capacities from 2002 to 2004 and spring 2023 of 41 percent and 49 percent of the total capacity, respectively.

Blue Mesa Reservoir is part of the Aspinall Unit in Colorado, which also includes Crystal Reservoir and Morrow Point Reservoir. Blue Mesa has the largest capacity of the Aspinall Unit reservoirs with a total capacity of 941.0 thousand acre-feet (kaf). Crystal Reservoir has a total capacity of 26.0 kaf and Morrow Point has a total capacity of 117.0 kaf. From 1980 to the implementation of the 2007

ROD, the average storage capacity (as a percentage of the total capacity) of Blue Mesa Reservoir was approximately 61 percent. From 2007 through 2024, the average storage capacity of Blue Mesa Reservoir was 56 percent. Blue Mesa Reservoir experienced the two lowest storage capacities in the winters of 2018 and 2021 of 21 percent and 22 percent of the total capacity, respectively.

Release operations under the 2019 Drought Response Operations Agreement (DROA) began in 2021 and included releases from Flaming Gorge, Navajo, and Blue Mesa. In 2022, DROA operations included releases from Flaming Gorge. In 2023, DROA operations included recovery of storage at Flaming Gorge, Navajo, and Blue Mesa (Reclamation 2024a).

While the alternatives analyzed may include the operation of reservoirs upstream of Lake Powell (CRSP UIUs) to protect Glen Canyon Dam infrastructure, these Operations are intended to remain within the scope of the existing Records of Decision (RODs) for the respective facilities. Accordingly, the Final EIS does not expand the geographic scope of analysis upstream of Lake Powell.[1]

TA 3.1.3 Lake Powell and Glen Canyon Dam

Lake Powell is a reservoir that is located primarily in southern Utah with a portion extending into northern Arizona. Inflows into Lake Powell originate from the mainstream Colorado River which is dammed near Page, Arizona by Glen Canyon Dam. The concrete arch dam was constructed from 1956 to 1964, and rises 710 feet above the bedrock of Glen Canyon. Lake Powell is relatively narrow and when it is full, stretches over 180 miles in length along the mainstream Colorado River in Glen Canyon. When full, it also includes approximately 25 miles of Cataract Canyon and 50 miles of the San Juan River. The water surface operating range of Lake Powell runs between 3,490 feet (corresponding to the minimum power pool) and 3,700 feet (corresponding to the top of Glen Canyon Dam spillway). The total live storage capacity of Lake Powell at the full pool elevation of 3,700 feet is 23.31 maf (excluding approximately 1.9 maf of Flood Control space).

The 2007 Final EIS and 2024 Final Supplemental EIS (SEIS) noted that groundwater adjacent to Lake Powell may increase or decrease in correlation with corresponding changes in pool elevations. This EIS will consider qualitative impacts on groundwater elevations adjacent to the reservoirs, including Lake Powell. The Arizona Department of Water Resources Groundwater Site Inventory website (ADWR 2025) tracks depth to water measurements for three active groundwater monitoring wells located adjacent to Lake Powell near Glen Canyon Dam. All three groundwater monitoring wells show a decreasing groundwater elevation trend beginning in the early 2000s, with the lowest groundwater elevations occurring in 2022.

Releases are typically made through the penstock intakes which are eight 15-foot diameter steel pipes that deliver water to the Glen Canyon Powerplant turbines. Releases can be made from Glen Canyon Dam from 3,490 feet down to 3,370 feet (corresponding to dead pool) through the four 8-

[1] While the Secretary will consider and prioritize operations at these facilities that are consistent with existing RODs, the Secretary retains the authority to operate outside those RODs if necessary. The modeling assumptions regarding operation of the Upper Initial CRSP Units presented in this Final EIS are not intended to, and do not, limit the Secretary's ability to operate these facilities as necessary to respond to hydrologic conditions in accordance with applicable federal law, including operations for the authorized purposes as stated in the 1956 Colorado River Storage Project Act.

foot diameter river outlet works, however, according to the 2024 Establishment of Interim Operating Guidance for Glen Canyon Dam during Low Reservoir Levels at Lake Powell Technical Memorandum, the river outlet works were not intended for long-term use at low reservoir levels (Reclamation 2024b). The cutoff elevation for routine operations of Glen Canyon Dam is considered 3,490 feet. Lake Powell also services direct water delivery to the City of Page, Arizona and the LeChee Chapter of the Navajo Nation through three different intakes, one of which can access water as low as 3,362 feet through the outlet works (Reclamation 2023a).

In 1968, the Colorado River Basin Project Act directed the Secretary to establish the Long-Range Operating Criteria (LROC) which was developed in 1970 to establish operating criteria for Colorado River reservoirs that were compliant with the Law of the River. According to the LROC "the objective shall be to maintain a minimum release of water from Lake Powell of 8.23 million acre-feet for that year." Releases above this amount only occurred if Upper Basin storage exceeded the requirements listed in Section 602(a) of the Colorado River Basin Project Act, storage in Lake Powell exceeded storage in Lake Mead, and if a spill was anticipated. Lake Powell and Glen Canyon Dam are operated consistent with the Colorado River Storage Project Act.

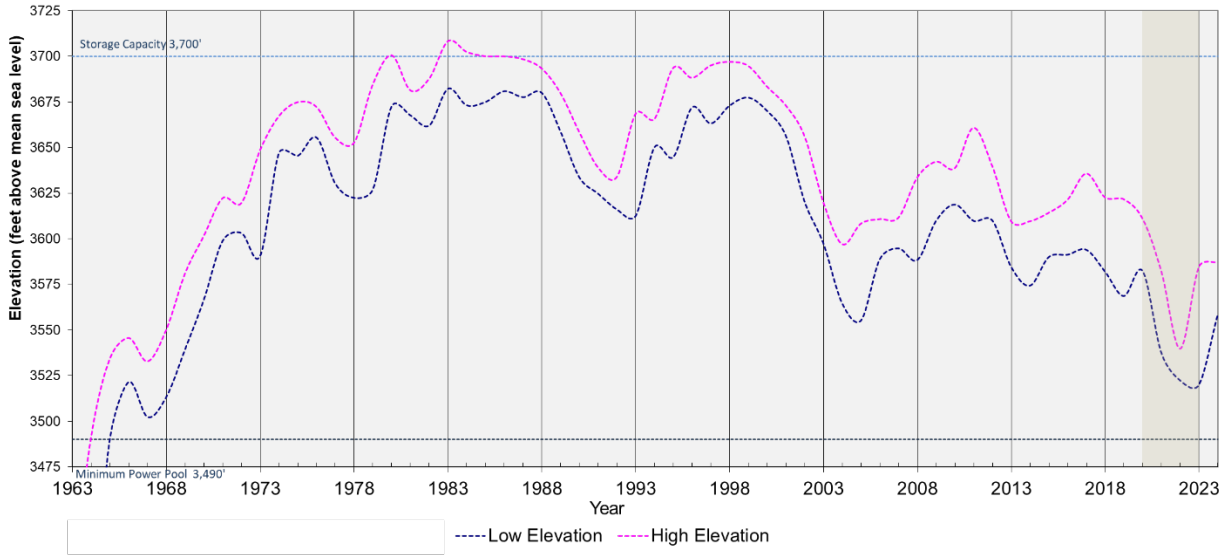
Unregulated inflows to Lake Powell from the Upper Basin vary year to year based on hydrologic conditions. According to a study that reconstructed historic conditions as far back as 600 CE, the current drought is the driest to occur since 800 CE (Wahl 2022). During the current 24-year drought period, unregulated water year (WY) inflows (the Colorado River WY refers to the period from October 1 to September 30 of the following calendar year [CY]) to Lake Powell ranged from 2.64 maf in 2002 to 15.97 maf in 2011 with an average of 8.29 maf (Reclamation 2025c). From 2020 to 2022, the Basin experienced three of the lowest consecutive inflow WYs on record, with inflows for those three years totaling around 15.5 maf (with 2021 having the lowest inflow of 3.5 maf). This continued period of drying and decrease in inflows in recent years has resulted in critically low elevations at Lake Powell.

Lake Powell began filling in 1963. The lake reached its highest elevation of 3,708.34 feet in 1983. Since Lake Powell is fed by inflows from the Upper Basin, water surface elevations are variable due to hydrologic conditions. To capture conditions since the implementation of the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), water surface elevation data were analyzed for the years 2008 through 2025 from the Bureau of Reclamation's (Reclamation's) Upper Basin Hydrologic dataset (Reclamation 2025b). The operating range during this period was between a low of 3,519.92 feet (occurring in 2023) and a high of 3,660.9 feet (occurring in 2011). The average operating elevation since the implementation of the 2007 Interim Guidelines was 3,602.3 feet, which is well below the average elevations in the 1980s and late 1990s, which were 3,683 feet and 3,679 feet, respectively. Since 2017, the annual average water surface elevation at Lake Powell has declined by approximately 87 feet, with the two largest year-over-year declines occurring in 2021 and 2022.

Lake Powell's annual high-water elevation and annual low-water elevation for 1963 through 2024 are shown in **Figure TA 3-1**. Note that these data include changes to elevations associated with operation of Lake Powell in accordance with the 2007 ROD, the Drought Contingency Plans (DCP; Reclamation 2019; implemented starting in 2020), and the Glen Canyon Dam Long-Term

Experimental and Management Plan Record of Decision (2016 LTEMP ROD; Reclamation 2016). The shaded box indicates four consecutive low elevation years (2020-2023), including the historical minimum of 3,520 feet (excluding the 1960s when Lake Powell was filling for the first time).

Figure TA 3-1
Lake Powell Annual High and Low Elevations (1963-2024)



Source: Reclamation 2025b

As mentioned previously, 2000 to 2024 is the driest 25-year period in more than a century. The start of these drought conditions in the 2000s triggered the need to outline specific operations to provide a greater degree of certainty to Colorado River water users about timing and volumes of potential water delivery reductions during low reservoir elevations. The result was the 2007 ROD, which adopted the 2007 Interim Guidelines (in effect through 2026) for the operation of Lake Powell and Lake Mead to manage potential water delivery reductions and provide flexibility to conserve and store water in the system.

The 2007 Interim Guidelines governed annual releases from Glen Canyon Dam based on the end of water year (EOWY) surface elevations of Lake Powell and Lake Mead. Different release volumes from Glen Canyon Dam were categorized by the following assigned Operational Tiers for Lake Powell[2]:

- Equalization Tier: releases are 8.23 maf or greater (to the extent necessary) to avoid spills or equalize storage in the two reservoirs as nearly as practicable. The "Equalization Volume" is the amount of water released above 8.23 maf in this Tier
- Upper Elevation Balancing Tier: releases depend on the elevation of Lake Powell and Lake Mead at the EOWY and are either 8.23 maf, or between 7.0 maf and 9.0 maf to balance contents

[2] The operational tiers are described in more detail in Sections 6.A through 6.D of the 2007 Interim Guidelines (Reclamation 2007b).

- Mid-Elevation Release Tier: releases depend on the elevation of Lake Powell and Lake Mead at the EOWY and are either 8.23 maf or 7.48 maf
- Lower Elevation Balancing Tier: releases between 7.0 maf and 9.5 maf as needed to balance contents

Since 2008, the most common Operational Tier has been the Upper Elevation Balancing Tier, which allowed releases from 7.0 maf to 9.0 maf (see **Table TA 3-1**). Glen Canyon Dam releases since 2007 have been between 7.0 maf to 12.52 maf (averaging 8.62 maf). This annual average of 8.62 maf is 1.13 maf lower than the average annual release from 1996 to 2007 of 9.75 maf, which can be attributed to hydrologic conditions in the Basin and operations under the 2007 Interim Guidelines.

Table TA 3-1
Summary of Lake Powell and Lake Mead Coordinated Operations 2008-2024

Year	Lake Powell Operations					Lake Mead Operations
	Operational Tier	Adjustment	Operating Year Unregulated Inflow (% Average) [6]	Release Volume (maf)	Equalization Volume (maf)	Operating Condition
2008	Upper Elevation Balancing	Equalization	126	8.98	0.75	Normal/Intentionally Created Surplus (ICS) Surplus
2009	Upper Elevation Balancing	None	106	8.24 [1]		Normal/ICS Surplus
2010	Upper Elevation Balancing	None	88	8.23		Normal/ICS Surplus
2011	Upper Elevation Balancing	Equalization	166	12.52	4.29 [2]	Normal/ICS Surplus
2012	Equalization	N/A	51	9.47	1.23 [3]	Normal/ICS Surplus
2013	Upper Elevation Balancing	None	53	8.23		Normal/ICS Surplus
2014	Mid-Elevation Release	N/A	108	7.48		Normal/ICS Surplus
2015	Upper Elevation Balancing	Balancing	106	9.00		Normal/ICS Surplus
2016	Upper Elevation Balancing	Balancing	100	9.00		Normal/ICS Surplus
2017	Upper Elevation Balancing	Balancing	124	9.00		Normal/ICS Surplus
2018	Upper Elevation Balancing	Balancing	48	9.00		Normal/ICS Surplus
2019	Upper Elevation Balancing	Balancing	135	9.00		Normal/ICS Surplus
2020 [4]	Upper Elevation Balancing	None	61	8.23		Normal/ICS Surplus and DCP Contributions

Year	Lake Powell Operations					Lake Mead Operations
	Operational Tier	Adjustment	Operating Year Unregulated Inflow (% Average) [6]	Release Volume (maf)	Equalization Volume (maf)	Operating Condition
2021 [4]	Upper Elevation Balancing	None	36	8.23		Normal/ICS Surplus and DCP Contributions
2022 [4]	Mid-Elevation Release	Adjusted in May 2022	63	7.00 [5]		Level 1 Shortage and DCP Contributions
2023 [4]	Lower Elevation Balancing	Balancing	140	8.58		Level 2 Shortage and DCP Contributions
2024 [4]	Mid-Elevation Release	None	83	7.48		Level 1 Shortage and DCP Contributions
2025 [4]	Mid-Elevation Release	None	50	7.48		Level 1 Shortage and DCP Contributions

Source: Adapted from Reclamation 2024c

[1] In 2009, while the scheduled release volume was 8.23 maf, the actual release was 8.24 maf due to rounding and a release of 5,702 acre-feet (af) above 8.23. Balancing did not occur in 2009.

[2] The total 2011 equalization volume was 5.52 maf, with 4.29 maf released in operating year 2011. The remaining equalization volume was released as soon as practicable and was released fully by December 31, 2011.

[3] Although Lake Powell operated in the Equalization Tier in 2011, 8.23 maf was released in operating year 2012 due to dry conditions. The additional release of 1.23 maf was operating year 2011 equalization water released during operating year 2012. The difference between 9.47 maf and 8.23 maf is due to rounding.

[4] Supplemental data for 2020 - 2024 provided by Annual Operating Plan (Reclamation 2020, 2021, 2022a, 2023b, 2024d, 2025d, 2025e).

[5] Lake Powell's release was reduced by 480,000 af during WY 2022 in May 2022 (Reclamation 2022b).

[6] The unregulated inflow statistics (percent average) are based on a mean of the 30-year period 1991-2020 for all years (9.6 maf).

Drought conditions from 2020 to 2022 triggered the need to supplement the 2007 Interim Guidelines with near-term provisions for addressing extremely low reservoir levels. The result was the 2024 Near-term Colorado River Operations Record of Decision (2024 ROD; Reclamation 2024e), which adopted modified operations to stabilize the declining reservoir elevations while still allowing for water releases and delivery to downstream water users. Beginning in 2024, releases from Lake Powell were based on the following modified Operational Tiers:

- Equalization Tier: remains the same as the 2007 ROD (Reclamation 2007b)
- Upper Elevation Balancing Tier: remains the same as the 2007 ROD (Reclamation 2007b)
- Mid-Elevation Release Tier: remains the same as the 2007 ROD (Reclamation 2007b) except that Reclamation may reduce releases to a minimum of 6.0 maf, if needed
- Lower Elevation Balancing Tier: remains the same as the 2007 ROD (Reclamation 2007b) except that Reclamation may reduce releases to a minimum of 6.0 maf, if needed
- If Lake Powell elevations are projected to drop below 3,500 feet, Reclamation facilities may be operated in a manner that protects the Colorado River system if hydrologic conditions require such action.

Releases from Glen Canyon Dam are scheduled on an annual, monthly, and hourly basis. Any sub annual releases comply with the 2016 LTEMP ROD and Supplemental Glen Canyon Dam Long-Term Experimental and Management Plan ROD (2024 LTEMP ROD) minimum daily and hourly flows of 5,000 cubic feet per second (cfs) at night and 8,000 cfs during the day through Glen Canyon Dam (Reclamation 2016).

TA 3.1.4 Lees Ferry Gaging Station

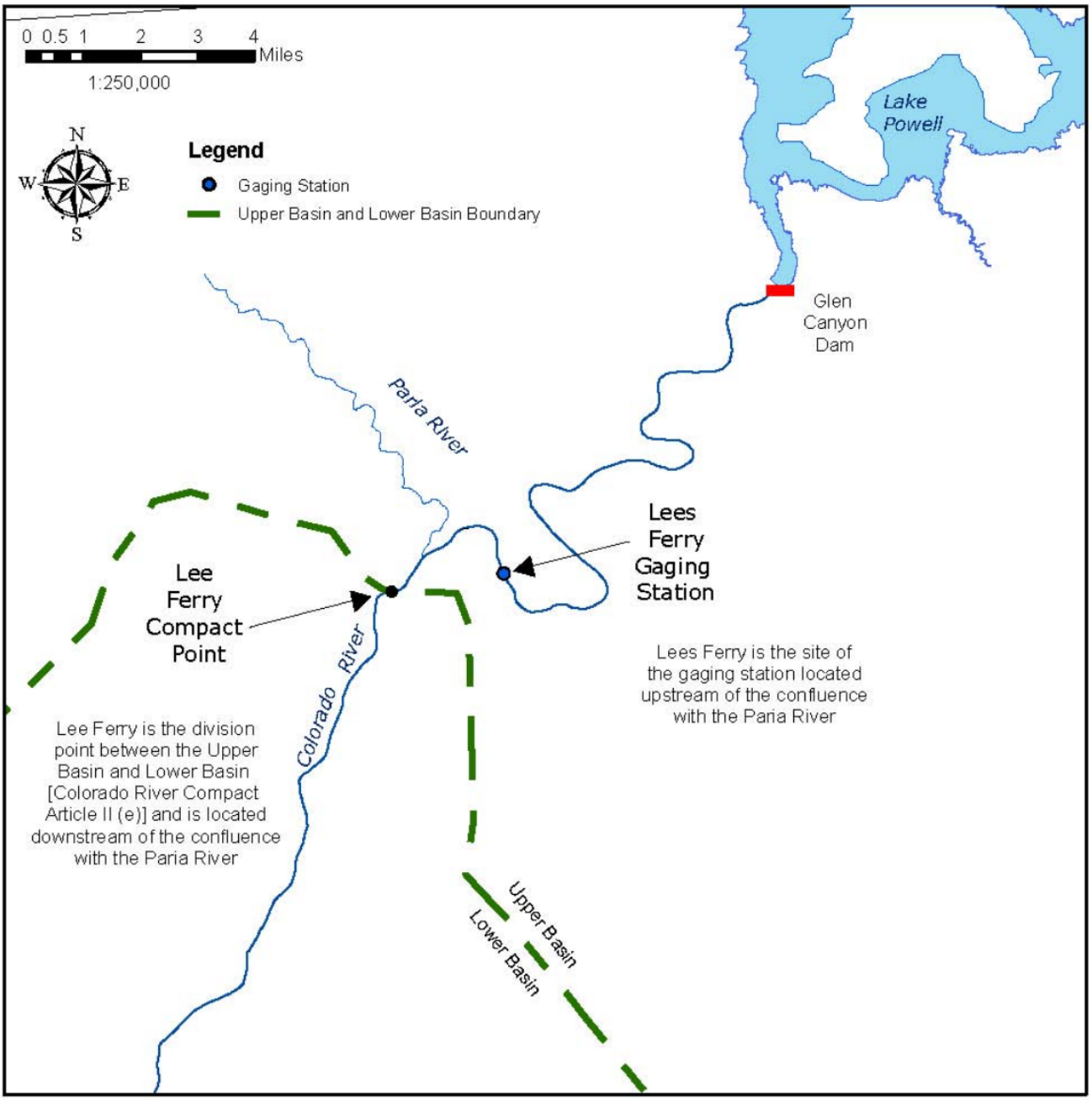
The Lees Ferry Gaging Station is located in Arizona, approximately 15.9 river miles (RMs) downstream of Glen Canyon Dam, but upstream of the confluence with the Paria River. The Lees Ferry Gaging Station differs from the Lee Ferry Compact Point, which is the division point between the Upper Basin and Lower Basin as established by the 1922 Colorado River Compact. The Lee Ferry Compact Point is located a few miles downstream of the Lees Ferry Gaging Station and is downstream of the confluence with the Paria River. **Figure TA 3-2** shows the difference between the Lees Ferry Gaging Station location and the Lee Ferry Compact Point Location.

Natural flows at Lees Ferry are calculated based on observed (gage) flow and corrected by Reclamation for upstream reservoir changes in storage and release, losses including evaporation, and depletions due to agriculture and domestic uses. The calculated natural flow record for Lees Ferry begins in 1922. Natural flows at Lees Ferry for 1906 to 1921 are also available from reconstructions using gage records in the Upper Basin.

From 1906 to 2007, the average annual natural flow at the Lees Ferry was calculated to be 14.9 maf and ranged from 5.4 maf to 24.4 maf. Since the implementation of the 2007 ROD (2008 to 2025), the annual natural flow at the Lees Ferry averaged 12.7 maf and has ranged from a low of 6.7 maf (2021) to 20.3 maf (2011). **Figure TA 3-3** shows the WY natural flows calculated at the Lees Ferry for 1906 through 2025.

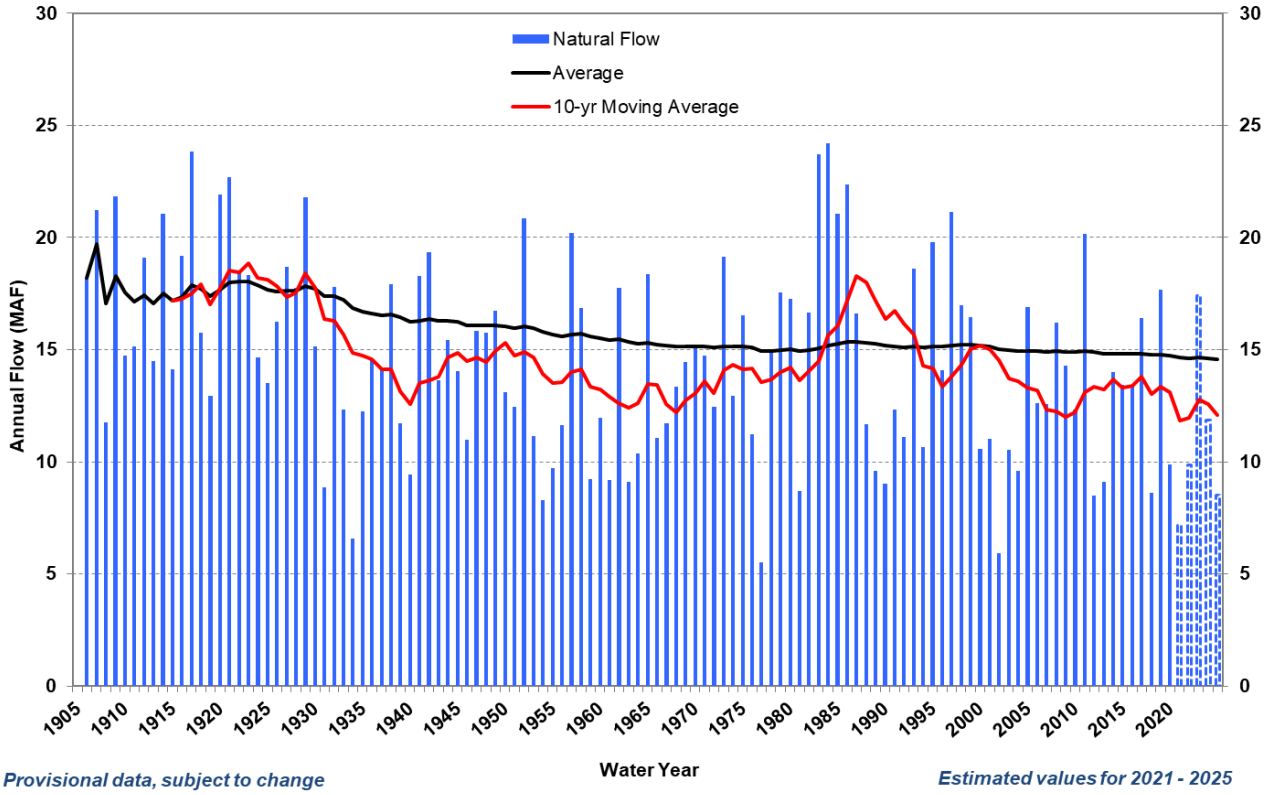
According to the 2020 *State of the Science* report, a 2-year average natural flow of less than 15.0 maf at Lees Ferry is considered a streamflow deficit (Lukas and Payton 2020). During the 1963–2007 period, the maximum 2-year average natural Lees Ferry flow was 24.0 maf in 1984. For comparison, since implementation of the 2007 ROD, the maximum 2-year average natural Lees Ferry flow was 16.27 maf in 2011. Other than the high flows in 2011, the 2-year average natural Lees Ferry flows since 2007 have been below 15.0 maf. Based on the 2020 *State of the Science* report's definition of a streamflow deficit, and the natural flow at Lees Ferry data, the system has been in a streamflow deficit since 2011 (Lukas and Payton 2020).

Figure TA 3-2
Lees Ferry Gaging Station and Lee Ferry Compact Point



Source: Reclamation 2007a

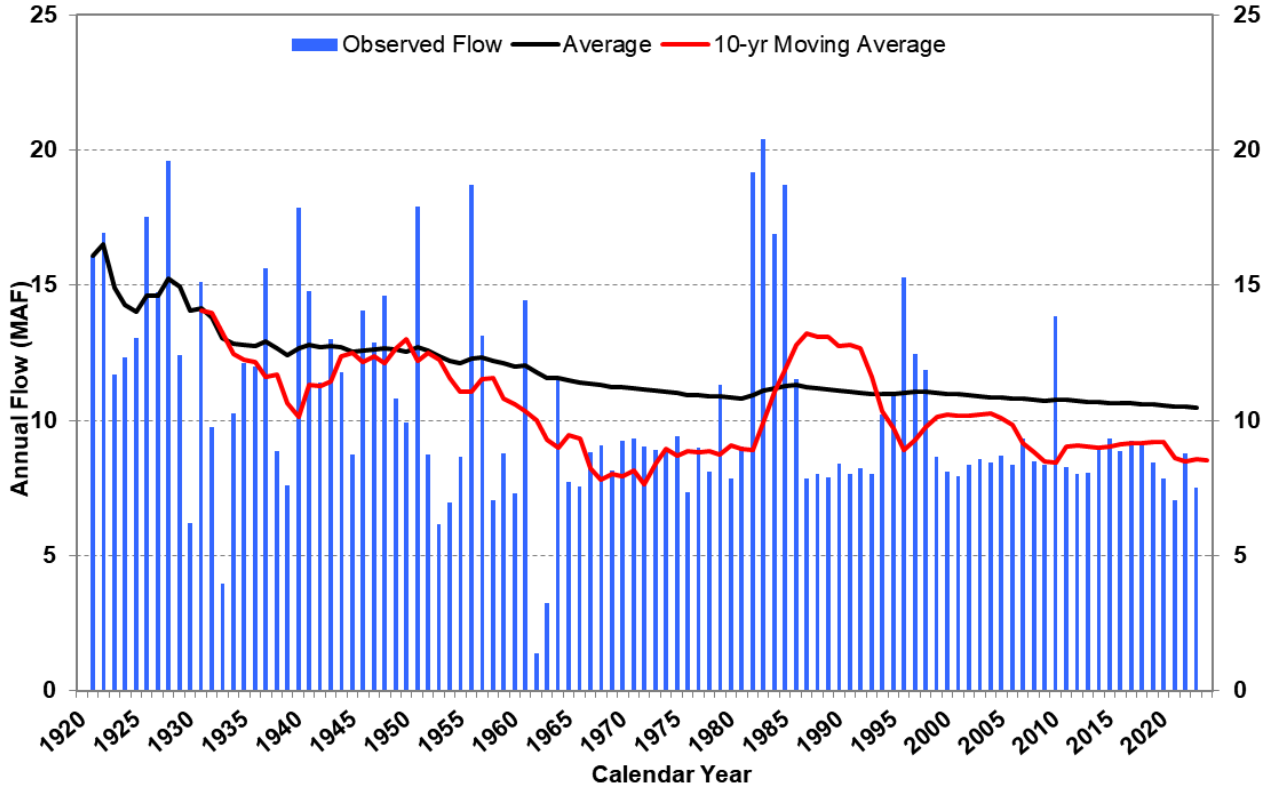
Figure TA 3-3
WY Colorado River Calculated Natural Flow at Lees Ferry Gaging Station, Arizona (1906-2025)



Source: Reclamation 2025f

The annual observed flow at Lees Ferry differs from natural flow in that it does not account for the above-mentioned factors and is simply the recorded gage data with infrastructure in place. The annual observed flow at Lees Ferry since Glen Canyon Dam was built (1963) until the 2007 ROD was implemented ranged from 1.4 maf (following when the dam was built in 1963) to 20.4 maf (1984) with an average of 9.8 maf. Since the implementation of the 2007 ROD (2008 to 2024), the annual observed flows at the Lees Ferry Gaging Station have generally decreased, ranging from 7.0 maf (in 2022) to 13.9 maf (in 2011) and averaging 8.8 maf. This average annual observed flow is approximately 1.0 maf less than the average observed flow from 1962-2007. **Figure TA 3-4** shows the observed flows recorded at the Lees Ferry for 1922 through 2024.

Figure TA 3-4
Colorado River Observed Flow at Lees Ferry Gaging Station, Arizona (1922-2024)



Source: Reclamation 2025f

TA 3.1.5 Glen Canyon Dam to Lake Mead

The narrow 292-mile reach between Glen Canyon Dam and Lake Mead flows through Marble Canyon, Glen Canyon, and GCNP. The reach through Glen Canyon is 15 miles long and the reach through the Grand Canyon reach is 277 miles long. Flows within this reach primarily consist of flow from Glen Canyon Dam releases but include contributions from perennial tributaries located between Glen Canyon Dam and Lake Mead. The two largest tributaries are the Paria River and Little Colorado River. The 95-mile long Paria River starts in the Grand Staircase-Escalante National Monument and joins the Colorado River approximately five miles downstream from Glen Canyon Dam. The 340-mile long Little Colorado River drains a region of the Colorado River watershed to the southeast of Lake Powell, including the Painted Desert. The smaller creeks entering the GCNP from side canyons include Bright Angel Creek, Shinumo Creek, Tapeats Creek, Kanab Creek, Havasu Creek, and Diamond Creek.

Based on historical United States Geological Survey (USGS) gage data, inflows from the Paria River and Little Colorado River make up approximately three percent of the total flow in this reach of the Colorado River (USGS 2025a). From 1906 to 2005, the annual inflow of the Paria River averaged 21 thousand acre-feet per year (kafy) and the Little Colorado River averaged 180.0 kafy. Since 2007, the annual inflows from the Paria River averaged 17.0 kafy and the Little Colorado River averaged 274.0

kaf. Just below the confluence of the Little Colorado River (USGS gage 09402500), the flows in Colorado River ranged from 7.56 maf to 14.24 maf (averaging 9.31 maf; USGS 2024).

The Stream Flow and Losses of the Colorado River in the Southern Colorado Plateau White Paper 5 (White Paper 5; Wang et al. 2020) stated that there is approximately 150.0 kaf a year of seepage loss around Glen Canyon Dam and this volume has remained consistent.

Downstream of Glen Canyon Dam is the incised Grand Canyon, which limits hydraulic connection to groundwater to sandbars. Debris flows from side canyons result in deposits into the Grand Canyon of boulders and sand to replenish sandbars during elevated flows. Refer to **TA 5**, Geomorphology and Sediment, for more details regarding physical geotechnical characteristics of the Grand Canyon. Effects on groundwater elevations through the Grand Canyon were not considered in the 2007 Final EIS or the 2024 Near-term Colorado River Operations Final SEIS (2024 Final SEIS). While the flows in the Colorado River would not affect groundwater in the region, changes to the groundwater systems in the Grand Canyon due to climate trends may be an additional environmental factor that affects flows in the Colorado River.

TA 3.1.6 Lake Mead and Hoover Dam

Lake Mead is a reservoir that is located on both sides of the Arizona-Nevada state line. Inflows into Lake Mead are from the Colorado River through Black Canyon, which is dammed by Hoover Dam and also from the Virgin River and Muddy River tributaries to the north of the reservoir. The concrete, thick arch dam was constructed from 1931 to 1936 and rises 726 feet as the highest concrete dam in the United States (U.S). When full, Lake Mead is 112 miles long.

The water surface elevation operating range of Lake Mead is set between 895 feet and 1,219.6 feet, with a maximum elevation of 1,229 feet. The total live storage capacity of Lake Mead at the full pool elevation of 1,219.6 feet is 26.12 maf (excluding 1.5 maf of Flood Control space).[3]

Groundwater basins adjacent to Lake Mead are generally small in size and are bound by zones of non-water bearing rock. Previous efforts in the 2007 Final EIS and 2024 Final SEIS noted that groundwater adjacent to Lake Mead may increase or decrease in correlation with changes in pool elevations. The Arizona Department of Water Resources Groundwater Site Inventory website (ADWR 2025) tracks depth to water measurements for one active groundwater monitoring well located to the south of Lake Mead, near the Detrital Wash. Groundwater elevations have remained steady since the groundwater monitoring well was installed in 1984 with the exception of two low groundwater elevation measurements in 2021 and 2022.

Beginning in 2011 and continuing for several years, Hoover Dam underwent improvements consisting of the installation of five new wide-head turbines to improve hydropower operations at lower water levels resulting in the lowering of the minimum power pool elevation from 1,050 feet to 950 feet. Low water level releases (below elevation 950 feet to elevation 895 feet) would continue through the four intake towers and penstocks but would no longer be able to be released through

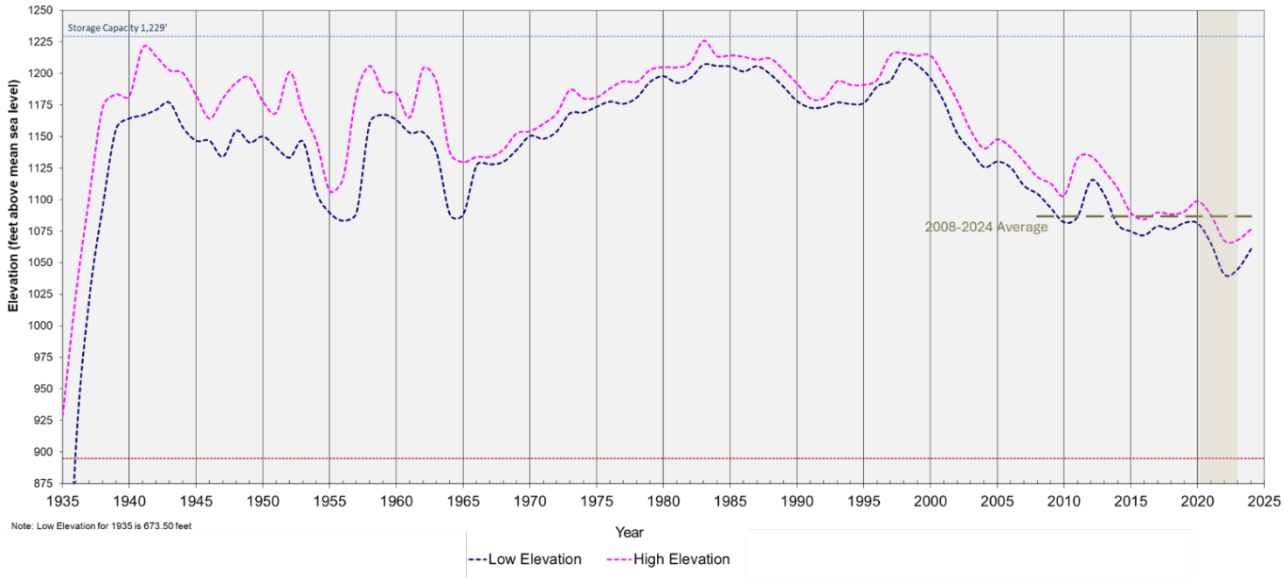
[3] Exclusive flood control space of 1.5 maf at elevation 1,219.6 feet as defined in the Field Working Agreement Between Department of the Interior, Bureau of Reclamation and Department of the Army, Corps of Engineers for Flood Control of Hoover Dam and Lake Mead, Colorado River, Nevada-Arizona, February 8, 1984.

the hydropower turbines; instead, below 950 feet, water would only be released through the river outlet works. When elevations drop below 895 feet (referred to as dead pool), water is no longer able to be delivered downstream from Hoover Dam.

Lake Mead took approximately four years to fill to an average annual water surface elevation of 1,172 feet following the construction of Hoover Dam in 1936, but levels were highly variable. From 1939 to 1963, until Glen Canyon Dam and Lake Powell came online, the reservoir's water surface elevation fluctuated from 1,098 feet to 1,195 feet. Average annual peak elevation steadied in 1983 at 1,215 feet, then decreased through the late 1980s and early 1990s. In 1998, the average annual elevation peaked again at 1,214 feet before sharply declining to a new low of 1,118 feet in 2007. From 1939 to 2007, the average annual water surface elevation of Lake Mead was 1,170 feet.

Since 2007, water surface elevations at Lake Mead have generally declined. Reclamation's hydrologic database collected water surface elevation data from 2008 through 2024 which showed that the average annual operating range was between 1,040.6 feet (2022) and 1,134.5 feet (2011). The average annual operating elevation was 1,086.8 feet, approximately 83.2 feet lower than the historical average annual from 1939 to 2007. **Figure TA 3-5** shows the annual high-water elevation and annual low-water elevation of Lake Mead from 1935 to 2024 with the average elevation of 1,086.8 feet from 2007 to 2024 shown as a dashed line, for reference.

Figure TA 3-5
Lake Mead Annual High and Low Elevations (1935-2024)



Source: Reclamation 2025b

The Compact apportioned 7.5 maf of water per year for beneficial consumptive use to the Lower Division States. The LROC established operating criteria for Colorado River reservoirs including criteria for Normal, Surplus, and Shortage operating conditions at Lake Mead pursuant to Section II(B) of the Supreme Court Decree in *Arizona v. California* 1964 and the 2006 Consolidated Decree.

Prior to the 2007 ROD, there were no objective criteria to reduce deliveries to Lower Basin water users below normal apportionment.

The 2007 ROD also adopted criteria for storing and delivering conserved Colorado River system and non-system water in Lake Mead. Water conserved under this program is called Intentionally Created Surplus (ICS). The program allowed for additional flexibility in meeting water needs during drought and bolstered Lake Mead during low reservoir conditions. The 2019 DCP modified and expanded the original ICS program. Since the 2007 ROD, Lake Mead has operated on a normal/ICS condition each year from 2008 through 2021 (refer to **Table TA 3-1**, Summary of Lake Powell and Lake Mead Coordinated Operations 2008-2024, above for Lake Mead's operating condition). In 2022, Reclamation declared the first ever Level 1 Shortage Condition for Lake Mead. Hydrologic conditions worsened and Lake Mead operated at a Level 2 Shortage Condition in 2023. In 2024 and 2025, Lake Mead operated in a Level 1 Shortage Condition. From 2020 through 2025, contributions from the Lower Basin DCP were required when the elevation of Lake Mead was below elevation 1,090 feet.

2007 Interim Guidelines shortage, DCP contributions, and ICS activity since the 2007 ROD have contributed to decreases in Hoover Dam releases. Annual Hoover Dam releases from Lake Mead ranged from 8.275 maf to 12.781 maf (averaging 10.199 maf) from 1996 through 2007 but have since ranged from 8.515 maf to 9.615 maf (averaging 9.185 maf) from 2008 through 2024.

Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaks during high-demand periods. Releases from Hoover Dam are also based on Flood Control regulations are directed by the U.S. Army Corps of Engineers (USACE). Approximately 1.5 maf of space must be reserved within Lake Mead at all times exclusively for Flood Control purposes.

TA 3.1.7 Hoover Dam to Lake Mohave

The 67-mile reach from Hoover Dam (Lake Mead) to Davis Dam forms Lake Mohave. The upper part of this reach consists of Pyramid Canyon, El Dorado Canyon, and Black Canyon. The steep walls of these canyons bound most of this reach. The narrow Lake Mohave is less than four miles across its widest point. The lake creates some minor side washes but flow within this reach is almost entirely comprised of releases from Hoover Dam (Reclamation 2007a).

Since the issuance of the 2007 ROD, releases from Hoover Dam have decreased to meet monthly elevation targets, resulting in lower river flows through this reach. The 2007 Interim Guidelines have reduced average annual releases from Hoover Dam by approximately 1.014 maf (annually averaging 9.185 maf).

The target water surface elevation range of Lake Mohave and Davis Dam were not affected by the 2007 Interim Guidelines, with target water surface elevation levels between elevation 633 feet to 645 feet. Lake Mohave generally reaches its lowest elevations in the fall as Reclamation aims to provide Flood Control capacity for runoff that results from hurricane-type storms from Baja California, Mexico. Lake Mohave generally reaches its highest elevations in the spring. The average storage in Lake Mohave has remained constant at approximately 1.6 maf over the past few decades, with an

average annual water surface elevation of approximately 640.8 feet from 1996 to 2007 and 640.9 feet since 2008.

With Black Canyon located directly downstream of Hoover Dam, the bedrock canyon limits the connection to groundwater with a few small sandbars. The 2007 Final EIS identified no anticipated impacts on the groundwater basins from the 2007 Interim Guidelines.

TA 3.1.8 Davis Dam to Lake Havasu

The 84-mile reach from Davis Dam to Parker Dam forms Lake Havasu, which provides a forebay and desilting basin that pumps water for delivery to the Metropolitan Water District of Southern California and Central Arizona Project service areas. Minor tributaries are located above the reservoir, but flow in this reach primarily consists of releases from Davis Dam.

Bill Williams River, the largest of the tributaries in this reach, flows directly into Lake Havasu. The small inflows (on the order of 50 cfs) from this tributary flow and are regulated by the USACE operations of Alamo Dam. Based on historical USGS gage data, from 1906 to 2007, the annual inflow ranged from 1,300 af to 702,000 af and averaged 102,000 af (USGS 2025b). Flood Control operations at the Alamo Dam occasionally contribute to increased flows to Lake Havasu. The 2007 Interim Guidelines did not affect these operations. Annual Alamo Dam releases from 2008 to 2022 have ranged from 15.4 af to 501,900 af and averaged 105,000 af. Bill Williams River flow contributions to the reach have remained unchanged.

Parker Dam is operated under the same rule curve that sets end-of-month target elevations as prior to the 2007 Interim Guidelines, maintaining Lake Havasu's water surface elevation between 445 and 450 feet. Seasonal adjustments to the reservoir's water surface elevation allow for Flood Control in the fall and higher water levels in the spring. The average annual elevation was 447.5 feet from 1996 to 2007, and approximately 447.7 feet from 2008 to 2022, remaining consistent for the last several decades.

This reach flows through two separate groundwater basins separated by the bedrock Topock Narrows: the Mohave Valley (north) and Chemehuevi Valley (south). Based on the 2007 Final EIS hydrologic and hydraulic models, the Mohave Valley aquifer, which is mostly alluvial fill, groundwater elevations were assumed to have decreased by approximately 0.25 feet since 2007. Water levels in the Chemehuevi Valley groundwater basin are assumed to have remained relatively consistent since 2007.

TA 3.1.9 Parker Dam to Cibola Gage

The 105-mile reach starting at Lake Havasu's Parker Dam is bounded on the downstream end by Reclamation's Cibola Gage. This reach primarily consists of releases from Parker Dam, which is considered the last major storage facility on the Colorado River.

Parker Dam releases are scheduled on a daily and hourly basis to meet demand for power while supplementing water supply downstream. The 2007 Interim Guidelines did not explicitly target Parker Dam operations but have resulted in decreased annual release rates since implementation. Current minimum releases of the dam are 1,600 cfs daily, 1,400 cfs hourly, releasing 95,000 af during

a 30-day month. The 2007 Final EIS stated Parker Dam releases from Lake Havasu ranged from 6.19 maf to 10.3 maf (averaged 7.4 maf) from 1996 to 2007. Since 2008, annual dam releases ranged from 6.2 maf to 6.7 maf (averaged 6.4 maf) through 2022. The average annual Parker Dam releases decreased by 1.0 maf post-implementation of the 2007 Interim Guidelines.

Two major diversion dams located in this reach are Headgate Rock Dam and Palo Verde Diversion Dam. The impoundments of these dams are used to facilitate the diversion of water for the Colorado River Indian Tribes and the Palo Verde Irrigation District. Current reservoir operations keep these reservoir levels at constant elevations.

The only large groundwater basin (mostly alluvial fill) within this reach is referred to by separate valley names: Parker Vally, Cibola Valley, and Palo Verde Valley. The 2007 Final EIS determined that groundwater elevations would decrease by approximately 0.15 feet to 0.30 feet in these areas based on hydrologic and hydraulic models and corresponding reductions in river flow. Therefore, groundwater levels have been assumed to have decreased since 2007 due to a decreasing trend in river flows.

TA 3.1.10 Cibola Gage to Imperial Dam

The 38-mile reach from Cibola Gage is bounded on the downstream end by Imperial Dam. Flows in this reach are primarily comprised of releases from Parker Dam. Imperial Dam is located approximately 18 miles northeast of Yuma, Arizona and provides enough increase in water surface elevation for gravity flow diversions to the All-American Canal (AAC) and the Gila Main Canal. The 2007 Interim Guidelines did not affect these diversions.

The Imperial Dam impoundment operates at a nearly constant elevation to meet water delivery requirements. The 2007 Interim Guidelines did not change operations of Parker Dam, but annual releases have decreased since 2008 due to decreased upstream releases from Lake Powell and Lake Mead, which translated to decreased inflows into Lake Havasu. Average flow rates in this reach ranged from 1,488 cfs to 18,168 cfs (averaged 8,931 cfs) from 1996 to 2007, and from 2,224 cfs to 18,751 cfs (averaged 7,632 cfs) since 2008. The reach has seen an average decrease of 1,299 cfs.

This reach is located in a narrow alluvial fill valley without irrigated agriculture, and many backwaters are located in the southern half of the reach. Groundwater elevations are assumed to have decreased in this reach since 2007.

TA 3.1.11 Imperial Dam to NIB

The 26-mile reach extends from Imperial Dam to the NIB between the U.S. and Mexico. The channel of the Colorado River through this reach is bounded by a system of levees. Flow through this reach is comprised of water released from Imperial Dam to make downstream deliveries, water leaked from the California sluiceway gates and return flow from Imperial Dam diversions.

Imperial Dam was constructed to raise the water surface elevation enough to provide gravity-controlled flow into the AAC on the California side and the Gila Gravity Main Canal on the Arizona side to meet water deliveries. The AAC diverts water for the Imperial Irrigation District, the

Coachella Valley Water District, the Yuma Project, and the City of Yuma. The AAC also has a desilting works used to remove sediment from the Colorado River prior to diversion into the AAC. The Gila Gravity Main Canal diverts water for Gila Valley, Yuma Mesa, and the Wellton-Mohawk area. Imperial Dam also regulates deliveries to Mexico.

Downstream of Imperial Dam, in the upper portion of the reach, flows are typically around 250 cfs to 350 cfs. Laguna Dam is located approximately 5 miles downstream from Imperial Dam and was initially constructed to divert water to the Yuma Project area. However, since the AAC was built, Laguna Dam has been used as a regulating structure to manage sluicing flows from Imperial Dam and to protect the toe of Imperial Dam. Approximately 9 miles downstream from Laguna Dam is the confluence with Gila River, which is a major tributary to the Colorado River.

The 2007 ROD did not affect the operations and flows in the upper portion of this reach. The Yuma Valley groundwater basin and the South Gila Valley groundwater basin were also not anticipated to be affected from the 2007 Interim Guidelines. Reclamation assumed that groundwater levels have remained essentially the same since 2007.

TA 3.1.12 NIB to SIB

The Morelos Diversion Dam, located 1.1 miles downstream of the NIB, impounds the majority of the water supply that is diverted by Mexico into the Reforma Canal. The dam is owned, operated, and maintained by Mexico per the 1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty). The dam's flow in the limitrophe to the SIB consists of water in excess of Mexico's scheduled delivery due to Flood Control operations at Hoover Dam, seepage from Morelos Diversion Dam, irrigation return flows, groundwater inflow, and any water released for environmental purposes in the Colorado River Delta.

To ensure the annual 1.5 maf water delivery under Normal Conditions per the 1944 Water Treaty, the Morelos Diversion Dam operations have not changed as a result of the 2007 ROD or the 2024 ROD. In Minute 323 to the 1944 Water Treaty, Mexico agreed to reductions and savings under low elevation reservoir conditions. Refer to **Appendix N**, International Border Region of the Colorado River, for more details related to an overview of previous binational coordination efforts.

The Flood Control releases from Lake Mead and Hoover Dam upstream are largely dependent on hydrologic conditions and therefore have potential impacts. The average flows to Mexico in excess of the required delivery volume were approximately 114,081 af from 1974 to 2012, until Warren H. Brock Reservoir was built to reduce excess flows at the NIB. Prior to completion, the 10-year annual average flow from 2003 to 2012 was 82,853 af. Since completion of the reservoir, flows in excess of the required delivery volume have decreased by approximately two thirds, or by 56,000 af, per year. Additionally, considerations for hydrologic conditions, rainfall events, and other operational variables are relevant to the volume of flows in excess of the required delivery volume.

This reach is in the Colorado River Delta groundwater basin and is referred to as the limitrophe. It is characterized as a dry or minimally flowing streambed with an annual rainfall of less than three inches. Flows in this reach can be from releases from Morelos Diversion Dam, various wasteway

discharges from the Yuma area irrigation system, or from nearby agricultural fields percolating into the hyporheic zone and subsurface alluvium.

Due to high groundwater levels in adjacent irrigated fields, the upper portion of the limitrophe is a gaining reach that receives perennial inflow from the groundwater basin. Depths to groundwater increase in the southern portions of the limitrophe reach, towards the SIB, which is considered a losing reach. Groundwater elevations in this reach dropped around 27 feet between 1960 and 2009 (refer to **Appendix N**, International Border Region of the Colorado River, for more details related to the affected environment description for the border region).

TA 3.2 Environmental Consequences

This section provides an analysis of the extent and magnitude of potential impacts on hydrologic resources under the No Action Alternative, four action alternatives (as described in **Appendix S**), the Continued Current Strategies (CCS) Comparative Baseline (as described in **Chapter 3 , Section 3.2.3**), and the Representative Preferred Alternative (as described in **Chapter 2**).

As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative Preferred Alternative which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval.

Methodology

Reclamation uses the Colorado River Simulation System (CRSS) model for long-term planning studies. CRSS simulates Basin conditions decades into the future (the full analysis period is through 2060) and can be used to account for hydrological uncertainty. CRSS is a monthly time-step model that produces reservoir elevations, releases and river flows as outputs. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model documentation. Analysis in this appendix uses output from CRSS.

Decision Making under Deep Uncertainty (DMDU) is the approach used for quantitative analysis. It is a non-probabilistic evaluation framework that compares alternatives based on their ability to meet specific performance criteria in many potential future conditions and analyzes how the alternatives respond to specific hydrologic conditions. Additional background and technical details about the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach.

Throughout the analysis there are three standard figures: conditional boxplots, robustness heatmaps, and vulnerability bar plots. Each type of figure explains key information regarding performance. When taken together, the figures provide a full picture of how the alternatives compare and whether significant negative impacts are reasonably foreseeable under each alternative. The conditional

boxplot figures show how the alternatives respond to different categories of preceding hydrology and enable a comparison of alternatives in specific hydrologic conditions (e.g., average conditions or dry conditions). To create these figures, all 34 years (2027–2060) from all 400 simulated futures (13,600 data points per alternative) are separated into five categories based on their preceding 3-year average Lees Ferry natural flow. Robustness heatmaps show the alternatives' ability to meet different levels of performance over one or more decades in the wide range of potential future conditions used in the analysis. Vulnerability bar plots provide complementary analysis to the robustness heatmaps by identifying the specific hydrologic conditions in which each alternative is likely to succeed or fail the preferred minimum performance level. For more information about these figures and detailed interpretation guidance, see **Chapter 3**, **Section 3.2.6**

Impact Analysis Area

The geographic scope of the hydrologic resources analysis is the Colorado River corridor from the upstream limits of full pool elevation of Lake Powell to the downstream limits of the SIB. Reservoirs upstream of Lake Powell are operated pursuant to their own RODs, which are not altered by the proposed alternatives.

Assumptions

The hydrologic resources results are direct outputs from CRSS. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation. All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (see **Appendix S**, Additional Description of Alternatives). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

Impact Indicators

The following indicators were used to assess impacts on hydrologic resources:

- **Reservoir elevations**: impacts on reservoir elevations due to operational activities
- **System storage**: impacts on system storage due to operational activities
- **Reservoir releases:** impacts on reservoir releases due to operational activities
- **River flows:** impacts on river flows due to operational activities
- **Groundwater**: qualitative impacts on groundwater adjacent to reservoirs and river reaches due to operational activities

TA 3.2.1 Issue 1: Reservoir Elevations

Issue 1 addresses how operational activities for the various alternatives would affect reservoir elevations. This includes comparing the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Lake Powell pool elevations
- Lake Mead pool elevations
- Impacts of modeling assumptions for Upper Basin and Lower Basin conservation activity on Lake Powell and Lake Mead storage

Lake Powell

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to EOWY and minimum water year elevations at Lake Powell. Note that the performance of the Lower Basin Priority (LB Priority) approach and the Lower Basin Pro Rata (LB Pro Rata) approach under the Supply Driven Alternative will not differ in Lake Powell elevations because they use the same operation of Lake Powell. Critical Lake Powell elevations are listed in **Table TA 3-2** below. The total live storage capacity of Lake Powell at the full pool elevation of 3,700 feet is 23.31 maf (excluding approximately 1.9 maf of Flood Control space).

Table TA 3-2
Critical Elevations at Lake Powell

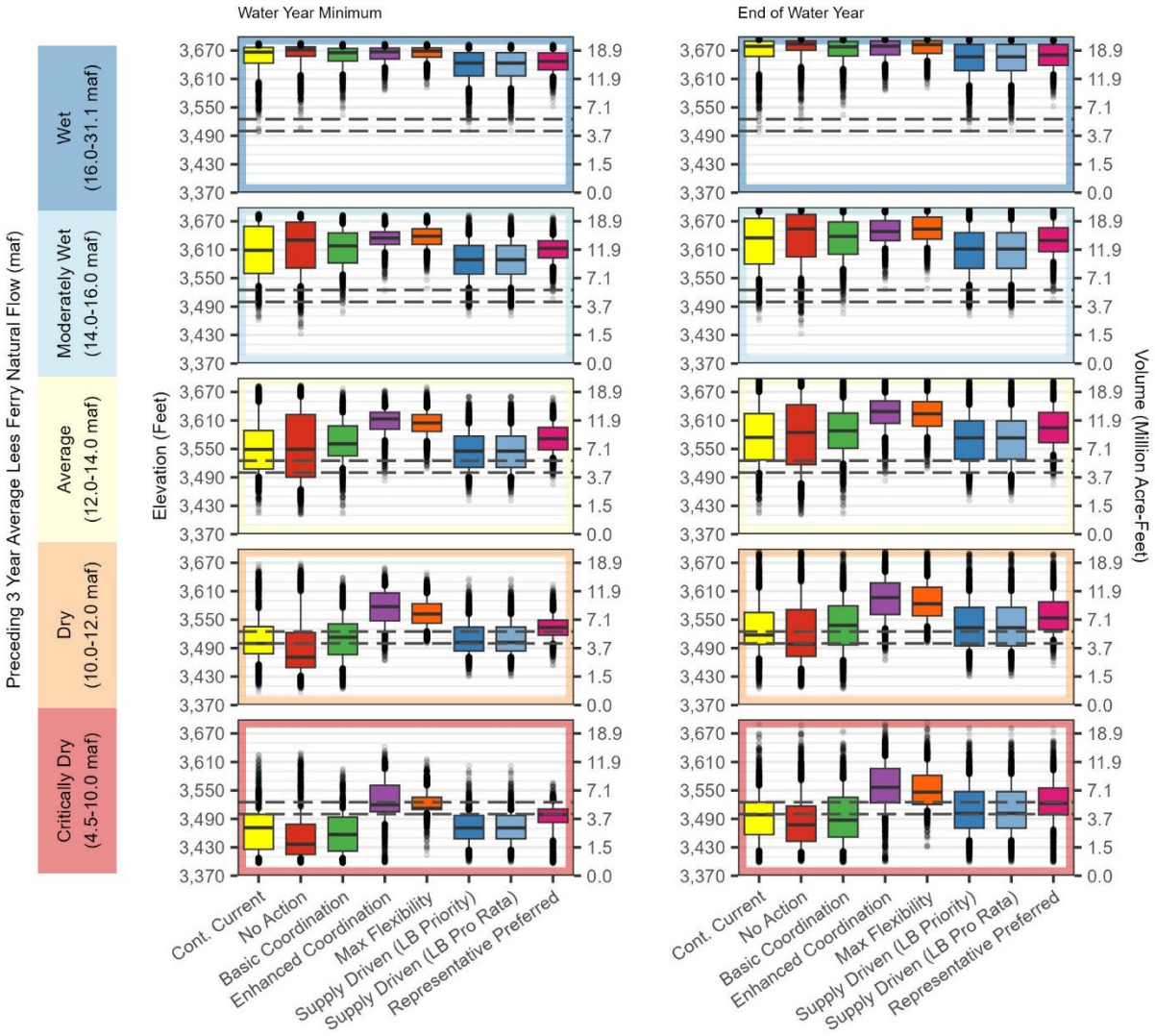
Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	3,700 feet	Top of Glen Canyon Dam spillway
Spill Avoidance	3,680 feet	At high elevations, releases deviate from the planned release for spill avoidance and infrastructure protection. Capacity between this elevation and the top of the spillway allows for 1.9 maf of Flood Control storage
Buffer Elevation	3,525 feet	35-foot buffer elevation above 3,490 feet; may trigger additional (within Record of Decision) releases from CRSP UIUs (Flaming Gorge, Navajo, and Blue Mesa Reservoirs) for certain alternatives
Buffer Elevation	3,500 feet	10-foot buffer elevation above 3,490 feet
Minimum Power Pool	3,490 feet	Water can only be released through the river outlet works below this elevation; no longer able to produce hydropower at Glen Canyon Dam; releases below this elevation are constrained; extended operations through the river outlet works may cause cavitation damage, tailrace scour and sediment deposition, and could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs
Dead Pool	3,370 feet	No longer able to release water downstream through Glen Canyon Dam

Figure TA 3-6 presents conditional boxplots of the minimum WY elevations and EOWY elevations at Lake Powell (feet) under varying hydrologic conditions, defined by the preceding three-year average of Lees Ferry natural flow. The figure shows how the alternatives perform across these flow categories. See **Table TA 3-3** and **Table TA 3-4** at the end of this TA for the full statistical summaries, including the maximum, 90th percentile, 75th percentile, median, 25th percentile, 10th percentile, and minimum elevations (feet). **Figure TA 3-6** visualizes the same data as **Table TA 3-3** (left column) and **Table TA 3-4** (right column) using two side-by-side conditional box plot panels. The bold center line of each box represents the median value. The bottom and top of each box captures the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and outliers are shown as dots.

In each flow category shown in the box plots, the critical elevation thresholds of 3,525 feet and 3,500 feet are identified with dashed lines. These elevations are important because they provide a 10-foot and a 35-foot buffer above 3,490 feet - the elevation below which water can only be released through the river outlet works. Operating below 3,490 feet limits the volume of water that can be

released, since water can only pass through the river outlet works. As described in **Chapter 1**, Purpose and Need, **Section 1.8.4.1**, there are infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs. There are additional impacts to hydropower associated with operating below 3,490 feet as this is minimum power pool.

Figure TA 3-6
Water Year Minimum and End of Water Year (EOWY) Elevations and Storage Volumes of Lake Powell



In the Average Flow Category for EOWY elevations, the 25th, 50th, and 75th percentiles (hereafter, 25th-75th percentiles) for all alternatives and the CCS Comparative Baseline remains above 3,500 feet. Similarly, all alternatives and the CCS Comparative Baseline have 25th-75th percentiles that

remain above 3,525 feet except for the No Action Alternative, which has a 25th percentile elevation of 3,517 feet. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have higher, less variable results centered around 3,625 feet, while the CCS Comparative Baseline and the No Action, Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives have median elevations around 3,580 feet.

In drier flow categories, the median EOWY elevations for the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives shift notably toward and below 3,500 feet, with the 25th-75th percentiles for the CCS Comparative Baseline and the No Action Alternative falling below 3,525 feet in the Critically Dry Flow Category (4.5-10.0 maf). The Enhanced Coordination and Maximum Operational Flexibility Alternatives show less of a decline across all flow categories; even in the Critically Dry Flow Category the 25th-75th percentiles for both remain above the critical threshold of 3,500 feet, with median reservoir elevations of 3,557 feet and 3,546 feet, respectively. In the Critically Dry Flow Category, median EOWY elevations shift below 3,500 feet for the Basic Coordination Alternative (3,487 feet), the No Action Alternative (3,478 feet), and the CCS Comparative Baseline (3,499 feet).

In the Dry Flow Category (10.0-12.0 maf) for EOWY elevations, the Representative Preferred Alternative has a median elevation of 3,554 feet with 25th and 75th percentiles of 3,529 feet and 3,588 feet, respectively. In the Critically Dry Flow Category for EOWY elevations, the Representative Preferred Alternative has a median elevation of 3,523 feet and decreasing variability, with 25th-75th percentiles spanning from 3,498 feet to 3,555 feet. With respect to the buffer elevation of 3,500 feet, the Representative Preferred Alternative remains above this threshold in more than 90 percent of years in the Dry Flow Category and in nearly 75 percent of years in the Critically Dry Flow Category; with respect to the buffer elevation of 3,525 feet, the Representative Preferred Alternative remains above this threshold in about 75 percent of years in the Dry Flow Category and nearly 50 percent of years in the Critically Dry Flow Category.

For the WY minimum panel, the comparisons across alternatives and flow categories are the same as in the EOWY elevations panel, but the distributions of elevations shift lower since Lake Powell generally reaches its minimum elevation in March before spring runoff begins and elevations increase by EOWY.

The alternatives and CCS Comparative Baseline generally perform similarly under Wet and Moderately Wet Flow Categories (16.0-31.1 maf and 14.0-16.0 maf), except for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) which has a lower median reservoir elevation. Performance deviations increase under drier conditions because operations at lower elevations vary widely across alternatives.

In the Dry Category for WY minimums, the Representative Preferred Alternative has a median elevation of 3,534 feet and an interquartile range (32 feet, calculated as 75th percentile minus 25th percentile) which is the smallest of any alternative. In the Critically Dry Flow Category for WY minimums, the Representative Preferred Alternative has a median elevation of 3,499 feet. With respect to the buffer elevation of 3,500 feet, the Representative Preferred Alternative remains above this threshold in 90 percent of years in the Dry Flow Category and about 50 percent of years in the

Critically Dry Flow Category; with respect to the buffer elevation of 3,525 feet, the Representative Preferred Alternative remains above this threshold in about 50 percent of years in the Dry Flow Category and about 10 percent of years in the Critically Dry Flow Category.

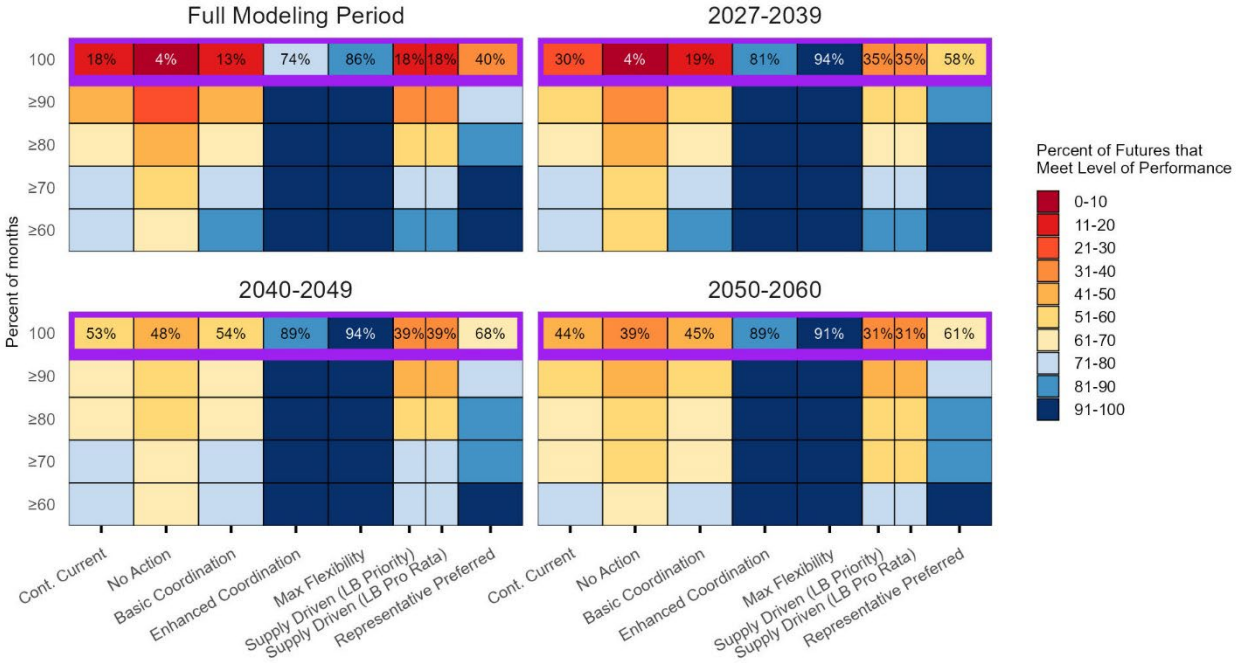
Lake Powell 3,500 Feet Robustness and Vulnerability

Figure TA 3-7 compares alternatives with respect to keeping Lake Powell above an elevation of 3,500 feet. As described above, this elevation is important because it provides a 10-foot buffer to protect critical infrastructure, water supply, and hydropower, which are critically impacted at an elevation of 3,490 feet.

The rows of the heat map reflect the percent of months in which Lake Powell elevation stays above 3,500 feet. Higher percentages of years are preferable and harder to achieve.

The purple highlighted row represents the preferred minimum level of performance and captures the percentage of futures that an alternative keeps Lake Powell above 3,500 feet in 100 percent of the months. 100 percent of months was chosen as the preferred minimum level of performance because of the importance of avoiding critical impacts on water deliveries and hydropower.

Figure TA 3-7
Lake Powell 3,500 Feet: Robustness.
Percent of futures in which Lake Powell elevation stays above 3,500 feet in the percent of months specified by each row



In the Full Modeling Period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred level of performance in 74 percent and 86 percent of the modeled futures, respectively, which is considerably more robust than the other alternatives. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB

Priority and LB Pro Rata approaches) Alternatives are the least robust and are only able to meet the preferred minimum performance in 18 percent, 4 percent, 13 percent, and 18 percent of futures, respectively.

Based on the planned length of this decision, it is important to note that in the first modeling period (2027-2039) the Enhanced Coordination and Maximum Operational Flexibility Alternatives are most robust, achieving the preferred minimum level of performance in 81 percent and 94 percent of futures respectively. The Supply Driven Alternative (both LB Priority and Pro Rata approaches) and the CCS Comparative Baseline are less robust meeting the preferred minimum performance in 35 percent and 30 percent of futures respectively. The No Action and Basic Coordination Alternatives are least robust in the first modeling period meeting the preferred minimum performance in only 4 percent and 19 percent of futures respectively.

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state (2027 begins with relatively low reservoir elevations) cause worse performance in the first decade.

In the lower rows of the heat maps, which reflect lower percentages of months where Lake Powell elevation stays above 3,500 feet, all alternatives improve.

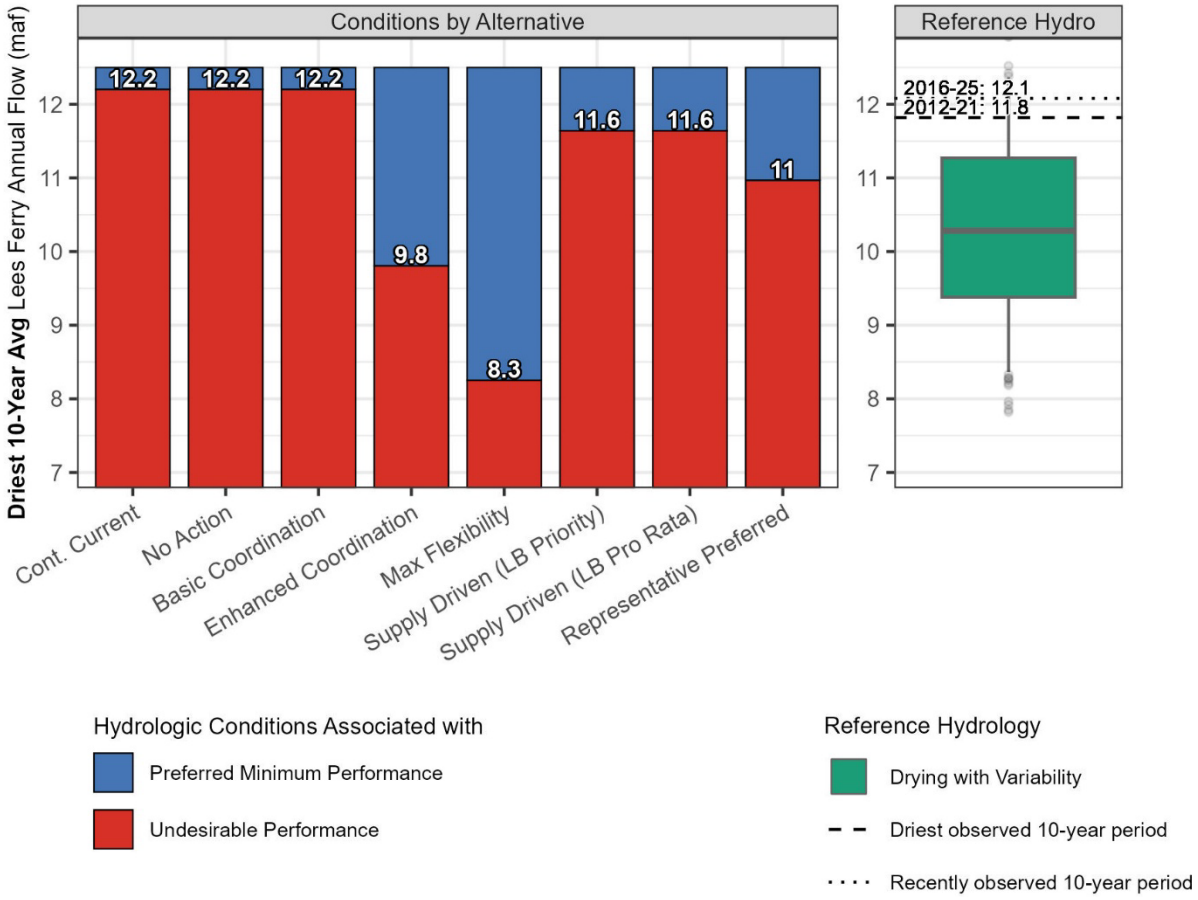
The Representative Preferred Alternative meets preferred level of performance in 40 percent of modeled futures in the Full Modeling Period. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 58 percent of futures in the first modeling period (2027-2039).

Figure TA 3-7 highlights the preferred minimum performance level of keeping Lake Powell above an elevation of 3,500 feet because this elevation provides a 10-foot buffer to protect critical infrastructure, water supply, and hydropower, which are critically impacted at an elevation of 3,490 feet. To identify the hydrologic conditions that could cause undesirable performance, the incidence of Lake Powell elevations dropping below 3,500 feet for at least one month in any year across the 34-year modeling period was analyzed in **Figure TA 3-8**.

The driest 10-year average Lees Ferry annual flow was identified as a good predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented along with the most recent and driest observed 10-year periods.

The CCS Comparative Baseline and the No Action, Basic Coordination, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are likely to result in undesirable performance under a wide range of hydrologic conditions, ranging between driest 10-year averages of 11.6 maf to 12.2 maf or lower (more than 75 percent of the reference hydrology traces). The Enhanced Coordination Alternative is vulnerable to undesirable performance if 10-year average flows are 9.8 maf or lower (fewer than 50 percent of the reference hydrology traces), and the Maximum Operational Flexibility Alternative is vulnerable to undesirable performance if 10-year average flows are 8.3 maf or lower (about 10 percent of the reference hydrology traces).

Figure TA 3-8
Lake Powell 3,500 Feet: Vulnerability.
Conditions that could cause Lake Powell elevation to fall below 3,500 feet in one or more months



The driest 10-year period in the observed record had an average of 11.8 maf and the most recent 10-year period had an average of 12.1 maf; the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to conditions near what has already occurred, both in the observed record and the most recent 10-year period.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of Lake Powell elevation below 3,500 feet under a 10-year average flow of 11 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in nearly 75 percent of the traces in the Drying with Variability Ensemble, which represents a drier future.

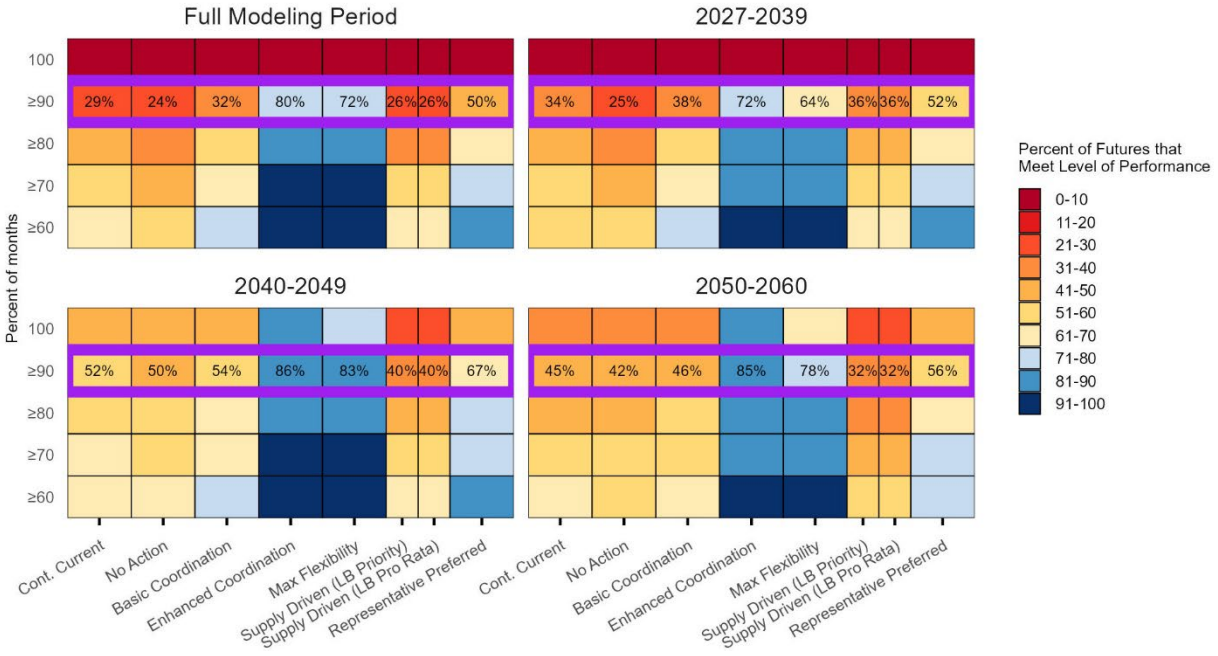
Lake Powell 3,525 Feet Robustness and Vulnerability

Figure TA 3-9 compares alternatives with respect to keeping Lake Powell above elevation 3,525 feet. This elevation is important because it provides a 35-foot buffer to protect critical infrastructure, water supply, and hydropower, which are critically impacted at an elevation of 3,490 feet.

The rows of the heat map reflect the percent of months in which Lake Powell elevation stays above 3,525 feet. Higher percentages of years are preferable and harder to achieve.

The purple highlighted row captures the preferred minimum level of performance of keeping Lake Powell above 3,525 feet in at least 90 percent of months. Greater than or equal to 90 percent of months was chosen as the preferred minimum level of performance because it provides a reasonable amount of flexibility to go below 3,525 feet occasionally in very dry hydrology while avoiding critical impacts on water deliveries.

Figure TA 3-9
Lake Powell 3,525 Feet: Robustness.
Percent of futures in which Lake Powell stays above 3,525 feet in the percent of months specified by each row



In the Full Modeling Period, the Enhanced Coordination and the Maximum Operational Flexibility Alternatives can meet the preferred minimum level of performance in 80 percent and 72 percent of the modeled futures, respectively, which is considerably more robust than the other alternatives. The CCS Comparative Baseline and No Action Alternative are only able to meet the preferred minimum performance in 29 percent and 24 percent of futures, respectively. The Representative Preferred Alternative meets preferred level of performance in 50 percent of modeled futures in the Full Modeling Period. For the more stringent performance standard of keeping Lake Powell above 3,525 feet in 100 percent of months, all alternatives and the CCS Comparative Baseline show poor levels of performance and can only meet the more stringent standard in 0-10 percent of futures.

Based on the planned length of this decision it is important to note that in the first subperiod (2027-2039) the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 72 percent and 64 percent of futures respectively. The CCS

Comparative Baseline and Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are similarly less robust meeting the preferred minimum performance in 34 percent, 38 percent, and 36 percent of futures respectively. The No Action Alternative is least robust meeting the preferred minimum performance in only 25 percent of futures in the first subperiod.

The Representative Preferred Alternative meets the preferred minimum performance level in 52 percent of futures in the first modeling period (2027-2039).

The alternatives meet the preferred minimum level of performance in greater percentages of futures in subperiods than the Full Modeling Period because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state (2027 begins with relatively low reservoir elevations) cause worse performance in the first decade than the following two decades. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the Full Modeling Period.

With respect to lower rows in the heatmap, which reflect lower percentages of years where Lake Powell elevation is above 3,525 feet, all alternatives improve.

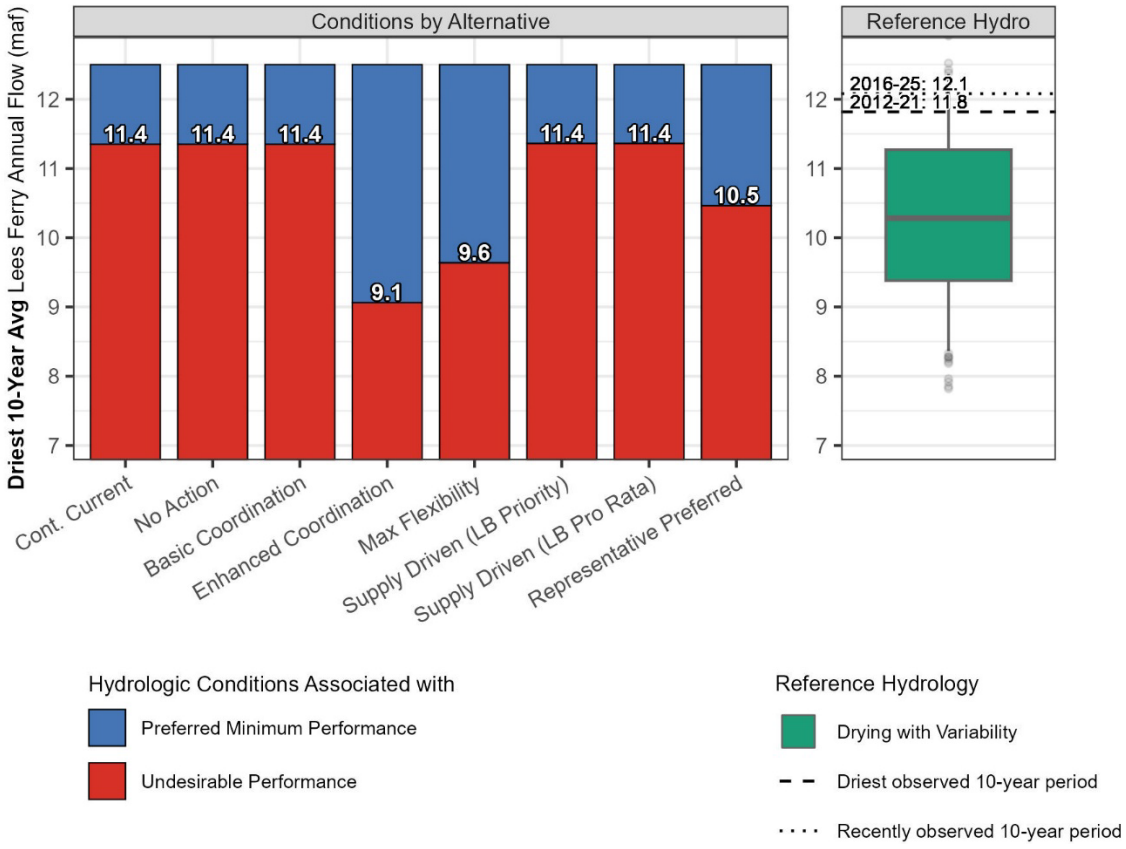
Figure TA 3-9 highlights the preferred minimum performance level of keeping Lake Powell elevation above 3,525 feet in more than 10 percent of months. To identify the hydrologic conditions that could cause undesirable performance, the incidence of Lake Powell elevations dropping below 3,525 feet in more than 10 percent of months across the 34-year modeling period was analyzed in **Figure TA 3-10**.

The driest 10-year average Lees Ferry annual flow was identified as a good predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented along with the most recent and driest observed 10-year periods.

The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to undesirable performance at 11.4 maf or lower. Vulnerabilities for the Enhanced Coordination and Maximum Operational Flexibility Alternatives occur at much lower driest 10-year average flows: 9.1 maf or lower and 9.6 maf or lower, respectively.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Powell elevation falling below 3,525 feet more than 10 percent of the time under a 10-year average flow of 10.5 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in more than 50 percent of the traces in the Drying with Variability Ensemble, which represents a drier future.

Figure TA 3-10
Lake Powell 3,525 Feet: Vulnerability.
Conditions that could cause Lake Powell elevation to fall below 3,525 feet in more than 10% of months



Lake Mead

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to minimum calendar year and end of calendar year (EOCY) elevations at Lake Mead. Critical elevations at Lake Mead listed in **Table TA 3-5** below preserve infrastructure and ensure Hoover Dam continues to operate under its intended design for purposes of downstream water releases. The total live storage capacity of Lake Mead at the full pool elevation of 1,219.6 feet is 26.12 maf (excluding approximately 1.5 maf of Flood Control storage available above the maximum operating elevation).

Figure TA 3-11 presents conditional boxplots of Lake Mead minimum CY and EOCY elevations (feet) and storage volumes under varying hydrologic conditions. The figure shows how the alternatives perform across these flow categories. See **Table TA 3-6** and **Table TA 3-7** at the end of this TA for the full statistical summaries. **Figure TA 3-11** visualizes the same data as **Table TA 3-6** (right column) and **Table TA 3-7** (left column) using two side-by-side conditional box plot panels. In each flow category, the critical thresholds of 1,000 feet and 975 feet are identified with dashed lines.

Table TA 3-5
Critical Elevations at Lake Mead

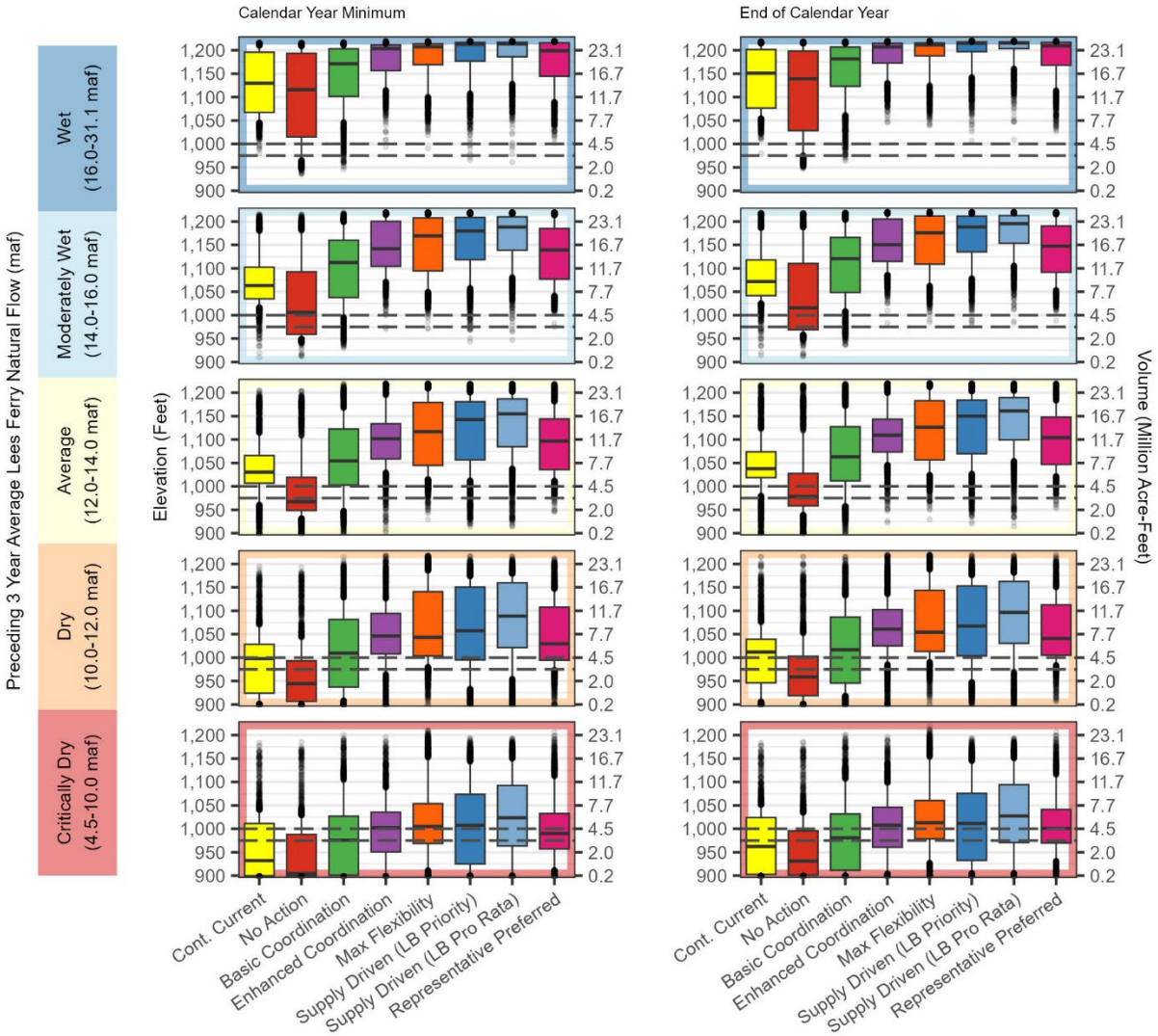
Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	1,221 feet	Top of Hoover Dam spillway.
Maximum Operating Elevation	1,219.6 feet	Allows for 1.5 maf of exclusive Flood Control space between elevations 1,219.6 feet and 1,229 feet (full pool).
Hydropower Critical Elevation	1,035 feet	Elevation at which 12 of the 17 turbines are no longer able to be used
Buffer Elevation	1,000 feet	Elevation of historical water supply significance that provides analysis continuity
Buffer Elevation	975 feet	25-foot buffer elevation[4] above minimum power pool (950 feet) for critical infrastructure and hydropower
Minimum Power Pool	950 feet	No longer able to produce hydropower at Hoover Dam; releases below this elevation are constrained.
Dead Pool	895 feet	No longer able to deliver water downstream through Hoover Dam.

In the Average Flow Category (12.0-14.0 maf) for EOCY elevations, the 25th-75th percentiles for all action alternatives and the CCS Comparative Baseline remain above the critical thresholds of 1,000 feet and 975 feet, while the median for the No Action Alternative (978 feet) falls between these critical elevations and the 25th percentile for the No Action Alternative drops below 975 feet. The Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have the highest medians and similar 75th percentile elevations, but the Maximum Operational Flexibility Alternative is more variable with a lower 25th percentile elevation. The CCS Comparative Baseline falls between the No Action and Basic Coordination Alternatives in terms of median elevation.

As flow categories get drier, the EOCY elevations for all alternatives and the CCS Comparative Baseline shift notably toward and below 1,000 feet and 975 feet in the Critically Dry Flow Category, with exception of the Maximum Operational Flexibility Alternative, which maintains a 25th percentile elevation of 979 feet. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have median elevations above the critical threshold of 1,000 feet even in the Critically Dry Flow Category. For the Basic Coordination Alternative in the Critically Dry Flow Category, the median elevation of 981 feet falls between the two critical thresholds. In the Critically Dry Flow Category, the CCS Comparative Baseline and the No Action Alternative have median elevations of 962 feet and 931 feet, respectively, and fall below both critical thresholds.

[4] A larger buffer above the hydropower and critical infrastructure elevation is used at Lake Mead (25 feet) than at Lake Powell (10 feet) because Reclamation is required to deliver water orders that have already been approved and therefore does not have as much flexibility to adjust releases from Hoover Dam as from Glen Canyon Dam.

Figure TA 3-11
Calendar Year Minimum and End of Calendar Year Elevations and Storage Volumes of Lake Mead



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

In the Dry Flow Category for EOCY elevations, the Representative Preferred Alternative has a median elevation of 1,041 feet and average variability compared to other alternatives and the CCS Comparative Baseline, with 25th and 75th percentiles of 1,005 feet and 1,113 feet. In the Critically Dry Flow Category for EOCY elevations, the Representative Preferred Alternative has a median elevation of 1,001 feet and decreasing variability, with 25th and 75th percentiles of 970 feet and 1,041 feet. With respect to the critical threshold of 975 feet, the Representative Preferred Alternative remains above this elevation in more than 90 percent of years in the Dry Flow Category and in close to 75 percent of years in the Critically Dry Flow Category; with respect to the critical threshold of 1,000 feet, the Representative Preferred Alternative remains above this elevation in more than 75

percent of years in the Dry Flow Category and in 50 percent of years in the Critically Dry Flow Category.

For the CY minimums panel, distributions of elevations shift lower since Lake Mead generally reaches its minimum elevation in July. The comparisons across alternatives and flow categories are similar to the EOCY elevations panel, but with the 25th-75th percentiles shifted slightly lower as well as some median elevations. In the Critically Dry Flow Category, the CY minimum elevation of Lake Mead falls below the critical threshold of 975 feet in more than 25 percent of years for all alternatives and the CCS Comparative Baseline. The CCS Comparative Baseline and No Action Alternative performed the worst with CY minimum elevations falling below 975 feet in more than 50 percent of years and almost 75 percent of years respectively.

In the Dry Category for CY minimums, the Representative Preferred Alternative has a median elevation of 1,030 feet and average variability compared to the other alternatives and the CCS Comparative Baseline, with 25th and 75th percentiles of 995 feet and 1,108 feet, respectively. In the Critically Dry Flow Category for CY minimums, the Representative Preferred Alternative has a median elevation of 990 feet and the least variability compared to the other alternatives and the CCS Comparative Baseline, with 25th and 75th percentiles ranging from 957 feet to 1,033 feet. With respect to the critical threshold of 975 feet, the Representative Preferred Alternative remains above this threshold in almost 90 percent of years in the Dry Flow Category and in more than 50 percent of years in the Critically Dry Flow Category; with respect to the critical threshold of 1,000 feet, the Representative Preferred Alternative remains above this threshold in about 75 percent of years in the Dry Flow Category and in nearly 50 percent of years in the Critically Dry Flow Category.

Lake Mead 975 Feet Robustness and Vulnerability

Figure TA 3-12 compares alternatives with respect to keeping Lake Mead above elevation 975 feet. Elevation 975 feet is important because it provides a 25-foot buffer to protect critical infrastructure and hydropower, which can no longer be produced at elevation 950 feet.

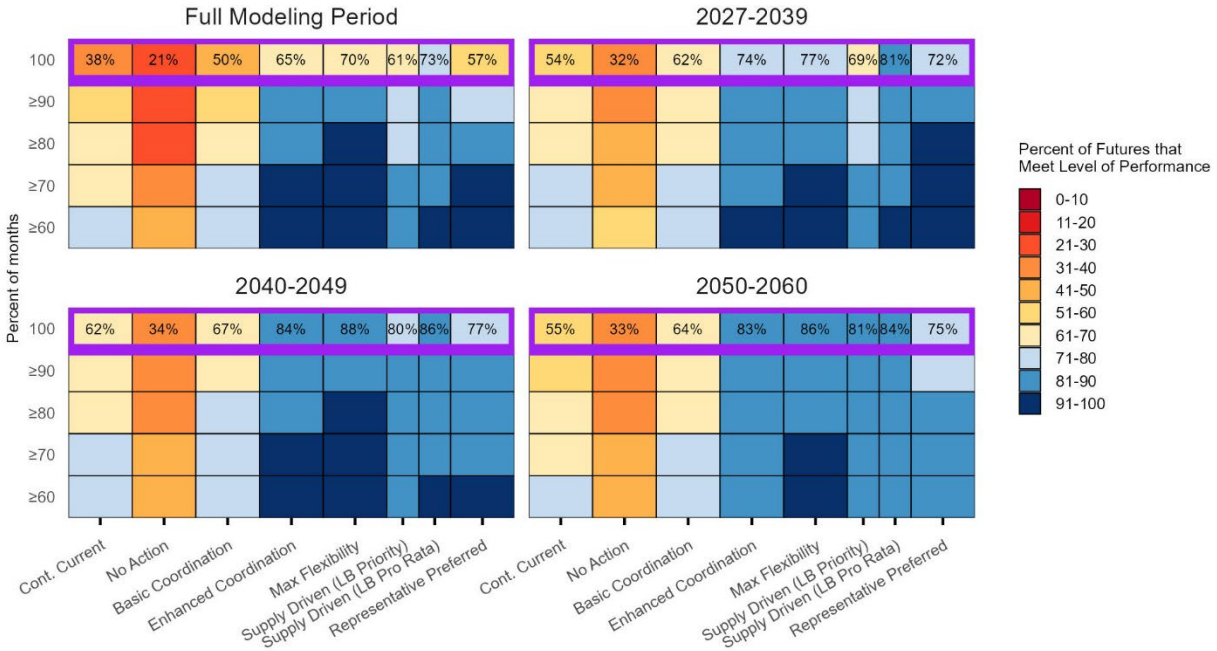
The rows of the heat map reflect the percent of months in which Lake Mead elevation stays above 975 feet. Higher percentages of years are preferable and harder to achieve.

The purple highlighted row represents the preferred minimum level of performance of keeping Lake Mead above 975 feet in 100 percent of months. 100 percent of months was chosen as the preferred minimum performance because of the importance of avoiding impacts on critical infrastructure and hydropower that occur if elevations dropped to 950 feet.

In the Full Modeling Period, the CCS Comparative Baseline and No Action Alternative meet the preferred minimum performance in 38 percent and 21 percent of futures, respectively. All action alternatives are more robust than the CCS Comparative Baseline and the No Action Alternative. The Basic Coordination Alternative meets the preferred minimum performance in 50 percent of futures. The Enhanced Coordination, Supply Driven (LB Priority approach) and Representative Preferred Alternatives are similarly robust, meeting the preferred minimum performance in 65 percent, 61 percent, and 57 percent of futures, respectively. The Maximum Operational Flexibility and Supply

Driven (LB Pro Rata approach) Alternatives are also similarly robust, meeting the preferred minimum performance in 70 and 73 percent of futures, respectively.

Figure TA 3-12
Lake Mead 975 Feet: Robustness.
Percent of futures in which Lake Mead elevation stays above 975 feet in the percent of months specified by each row



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

The action alternatives and the CCS Comparative Baseline show increasing robustness with darker shades of blue, as the specified frequency is relaxed in lower rows. Even when the frequency is relaxed to keeping Lake Mead above 975 feet only 60 percent of the time, the No Action Alternative only achieves the preferred minimum performance in 41-50 percent of futures.

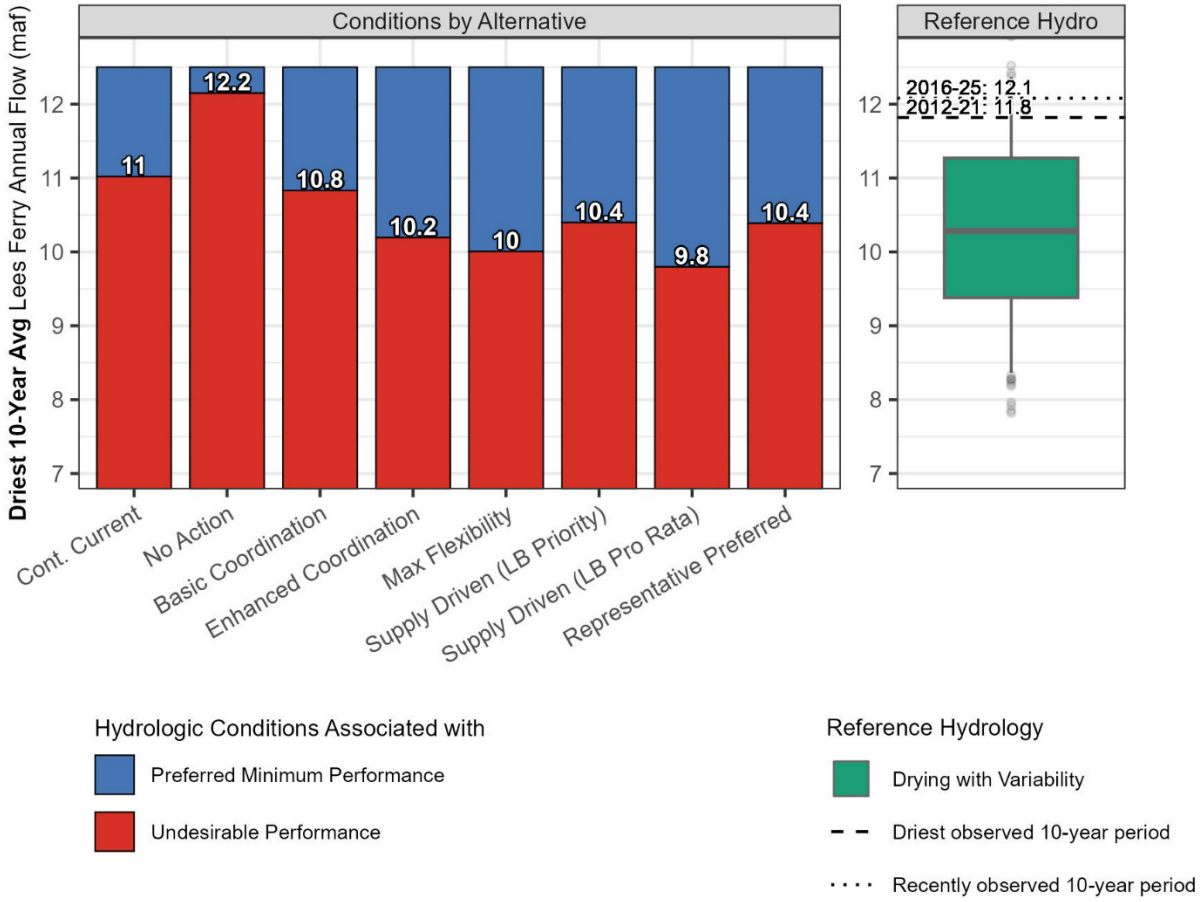
In the first subperiod (2027-2039) the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives are most robust meeting the preferred minimum performance in 74 percent, 77 percent, and 81 percent of futures respectively. The CCS Comparative Baseline, and the Basic Coordination and Supply Driven (LB Priority approach) Alternatives are somewhat less robust meeting the preferred minimum performance in 54 percent, 62 percent and 69 percent of futures respectively. The No Action Alternative is least robust in the first modeling period meeting the preferred minimum performance in only 32 percent of futures.

Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 72 percent of futures in the first modeling period.

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. The robustness ranking across the three alternatives in each subperiod is generally consistent with the ranking in the Full Modeling Period.

Figure TA 3-12 highlights the preferred minimum performance level of keeping Lake Mead elevation above 975 feet in one or more months because this provides a 25-foot buffer for critical infrastructure and hydropower, which are critically impacted at an elevation of 950 feet. To identify the hydrologic conditions that could cause undesirable performance, the incidence of Lake Mead elevations dropping below 975 feet for at least one month in any year across the 34-year modeling period was analyzed in **Figure TA 3-13**.

Figure TA 3-13
Lake Mead 975 Feet: Vulnerability.
Conditions that could cause Lake Mead elevation to fall below 975 feet in one or more months



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

The driest 10-year average Lees Ferry annual flow was identified as a good predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented along with the most recent and driest observed 10-year periods.

The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives are vulnerable to undesirable performance at 10-year average flows of 10.2 maf or lower, 10.0 maf or lower, and 9.8 maf or lower, respectively. About 50 percent of the reference hydrology traces include averages this low or lower. The Supply Driven Alternative (LB Priority approach) is vulnerable to undesirable performance at a 10-year average flow of 10.4 maf or lower, which falls between the 50th and 75th percentiles of the reference hydrology ensemble. The CCS Comparative Baseline and the Basic Coordination Alternative are vulnerable to undesirable performance at 10-year average flows of 11.0 maf or lower and 10.8 maf or lower, respectively; about 75 percent of the reference hydrology traces include averages this low or lower.

The No Action Alternative is the most vulnerable, with a 10-year average flow of 12.2 maf or lower leading to undesirable performance. The driest 10-year period in the observed record had an average Lees Ferry flow of 11.8 maf and the most recent 10-year period had an average Lees Ferry flow of 12.1 maf; the No Action Alternative is vulnerable to conditions that are wetter than what has already occurred, both in the most recent and driest observed 10-year periods.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of Lake Mead elevation falling below 975 feet under a 10-year average flow of 10.4 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in about 50 percent of the traces in the Drying with Variability Ensemble, which represents a drier future.

Lake Mead 1,000 Feet Robustness and Vulnerability

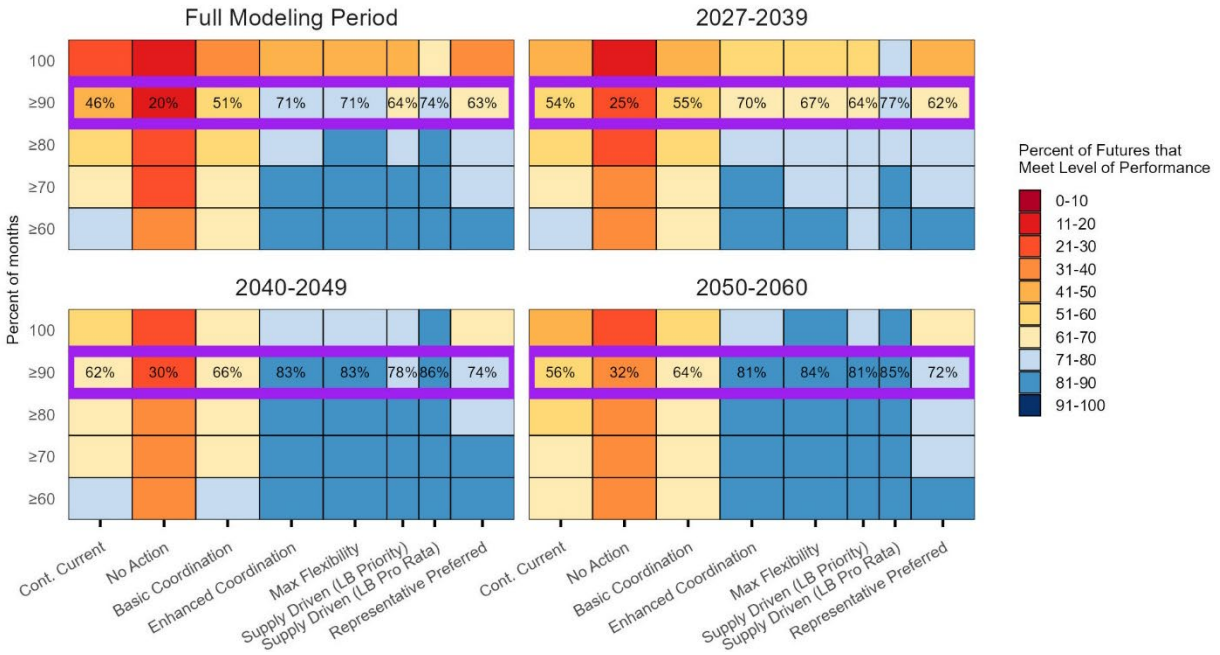
Figure TA 3-14 compares alternatives with respect to keeping Lake Mead's elevation above 1,000 feet, which is an elevation of historical significance to water supply that provides analysis continuity.

The rows of the heat map reflect the percent of months in which Lake Mead elevation stays above 1,000 feet. Higher percentages of years are preferable and harder to achieve.

The purple highlighted row represents the preferred minimum level of performance and captures the percentage of futures that an alternative keeps Lake Mead above 1,000 feet in 90 percent or more of the months. This threshold was chosen as the preferred minimum level of performance because it provides a reasonable amount of flexibility to go below 1,000 feet occasionally in very dry hydrology.

In the Full Modeling Period, the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives are similarly robust, meeting the preferred minimum level of performance in 71 percent, 71 percent, 64 percent, and 74 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative are the least robust, meeting the preferred minimum performance in 46 percent and 20 percent of futures, respectively.

Figure TA 3-14
Lake Mead 1,000 Feet: Robustness.
Percent of futures in which Lake Mead elevation stays above 1,000 feet in the percent of months specified by each row



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Based on the planned length of decision, it is important to note that in the first decade (2027-2039) Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives are similarly robust, meeting the preferred minimum level of performance in 70 percent, 67 percent, 64 percent, and 77 percent of futures respectively. The CCS Comparative Baseline and Basic Coordination Alternatives are somewhat less robust, meeting the preferred minimum performance in 54 percent and 55 percent of futures respectively. In the first modeling period, the No Action Alternative is the least robust, meeting the preferred minimum performance in 25 percent of modeled futures.

The Representative Preferred Alternative meets the preferred minimum level of performance in 63 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 62 percent of futures in the first modeling period (2027-2039).

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state

(2027 begins with relatively low reservoir elevations) cause worse performance in the first decade. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the Full Modeling Period.

With respect to lower rows in the heatmap which reflect lower percentages of years where Lake Mead elevation is above 1,000 feet, all alternatives improve, although the No Action Alternative is only able to meet the most relaxed performance standard (e.g., greater than or equal to 60 percent of months) in 31-40 percent of modeled futures.

Figure TA 3-14 highlights the preferred minimum performance level of keeping Lake Mead elevation above 1,000 feet in more than 90 percent of months because this represents an elevation of historical significance to water supply that provides analysis continuity. To identify the hydrologic conditions that could cause undesirable performance, the incidence of Lake Mead elevations dropping below 1,000 feet in more than 10 percent of months across the 34-year modeling period was analyzed in **Figure TA 3-15**.

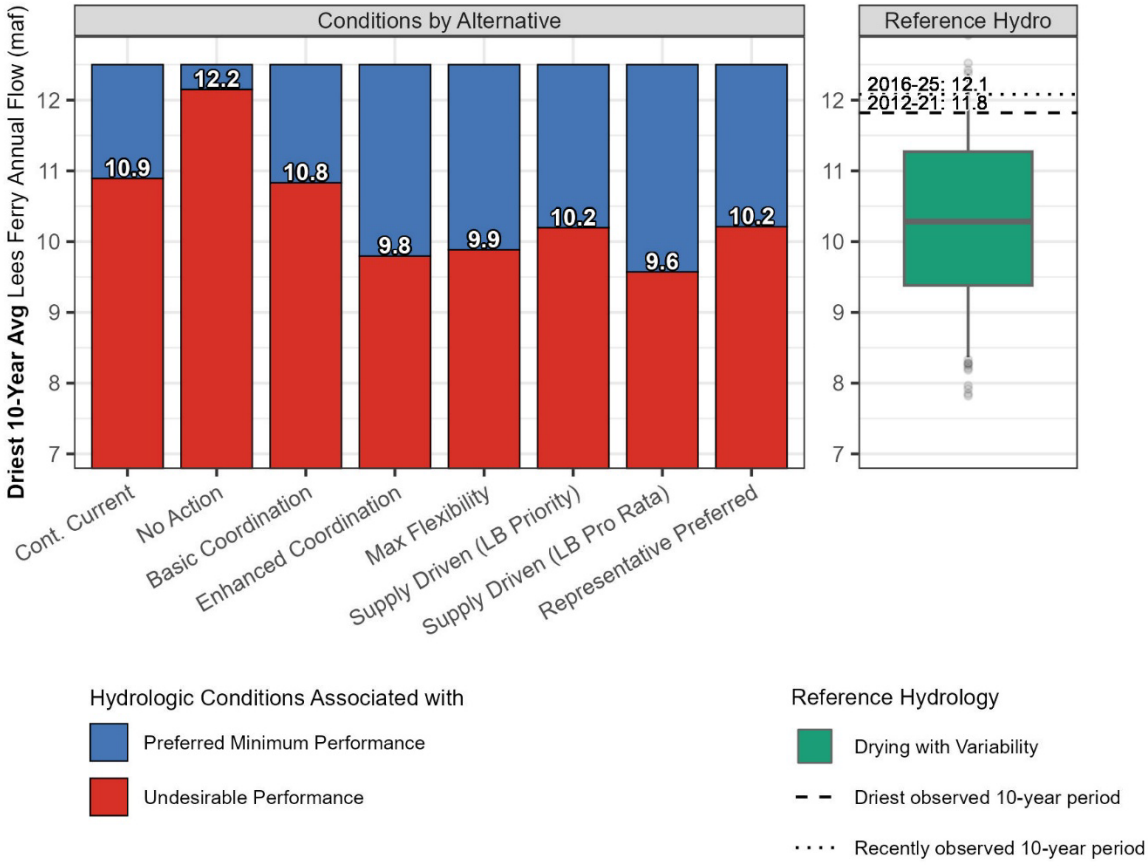
The driest 10-year average Lees Ferry annual flow was identified as a good predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented along with the most recent and driest observed 10-year periods.

The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives are vulnerable to undesirable performance at 10-year average Lees Ferry flows of 9.8 maf or lower, 9.9 maf or lower, and 9.6 maf or lower, respectively. These conditions are slightly below the 50th percentile of the reference hydrology ensemble, meaning that about 50 percent of the traces in the reference hydrology ensemble are wetter than these values. The Supply Driven Alternative (LB Priority approach) is vulnerable to undesirable performance at 10-year average flows of 10.2 maf or lower, which is near the 50th percentile of the reference hydrology ensemble. The Basic Coordination Alternative and the CCS Comparative Baseline are vulnerable to undesirable performance at 10-year average flows of 10.8 maf or lower and 10.9 maf or lower, respectively, which are slightly below the 75th percentile of the reference hydrology ensemble.

The No Action Alternative is the most vulnerable, with a 10-year average flow of 12.2 maf or lower leading to undesirable performance in the modeling results. The driest 10-year period in the observed record had an average Lees Ferry flow of 11.8 maf and the most recent 10-year period had an average Lees Ferry flow of 12.1 maf; the No Action Alternative is vulnerable to conditions wetter than what has already occurred, both in the most recent and driest observed 10-year periods.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Mead elevation falling below 1,000 feet more than 10 percent of the time under a 10-year average flow of 10.2 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in about 50 percent of the traces in the Drying with Variability Ensemble, which represents a drier future.

Figure TA 3-15
Lake Mead 1,000 Feet: Vulnerability.
Conditions that could cause Lake Mead elevation to fall below 1,000 feet in more than 10% of months



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Impacts of Modeling Assumptions for Upper Basin and Lower Basin Conservation Activity on Lake Powell and Lake Mead Storage

The following section describes the impacts of modeling assumptions for conservation activities for the various alternatives by showing how removing all conservation activity results in differences to reservoir elevations at Lake Powell and Lake Mead.

Table TA 3-8 below summarizes the various conservation mechanisms for each action alternative. All action alternatives, except for the Basic Coordination Alternative, incorporate mechanisms related to the storage and delivery of newly conserved water in Lake Powell and Lake Mead. Refer to **Appendix S,** Addtional Description of Alternatives, for specifics related to each alternative's conservation mechanisms. While the No Action and Basic Coordination Alternatives do not include mechanisms to conserve and store water in Lake Powell or Lake Mead, the alternatives include assumptions for the delivery of existing ICS that was conserved prior to

2027. For modeling purposes only, assumptions about storage and delivery of previously conserved water were developed to show the maximum impacts of the conservation pools on reservoir elevations and downstream flows; they are not intended to represent specific activities or constrain individual users. Refer to **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water, for more details related to the conservation assumptions for each alternative. The modeling results that incorporate the assumptions in this paragraph are labeled 'conservation-on'.

Table TA 3-8
Summary of Conservation Mechanisms by Alternative

Alternative	Conservation Pool Volume	Conservation Pool Mechanism
Continued Current Strategies Comparative Baseline	0.5 maf	Upper Basin pool in Lake Powell
	4.2 maf	Lower Basin pool in Lake Mead
No Action		No new mechanism; delivery of pre-2027 conservation only
Basic Coordination		No new mechanism; delivery of pre-2027 conservation only
Enhanced Coordination	2 maf	Upper Basin pool in Lake Powell
	5 maf	Lower Basin pool in Lake Mead
	2 maf	Protection Pool in Lake Mead
Maximum Operational Flexibility	5 maf	Upper Basin pool (distributed strategically across Lake Powell and Lake Mead)
	3 maf	Lower Basin pool (distributed strategically across Lake Powell and Lake Mead)
Supply Driven (both approaches)	3 maf	Upper Basin pool in Lake Powell
	8 maf	Lower Basin pool in Lake Mead
Representative Preferred	3 maf	Upper Basin pool in Lake Powell
	7 maf	Lower Basin pool in Lake Mead
	1 maf	Federally Managed Water Resources Pool in Lake Mead

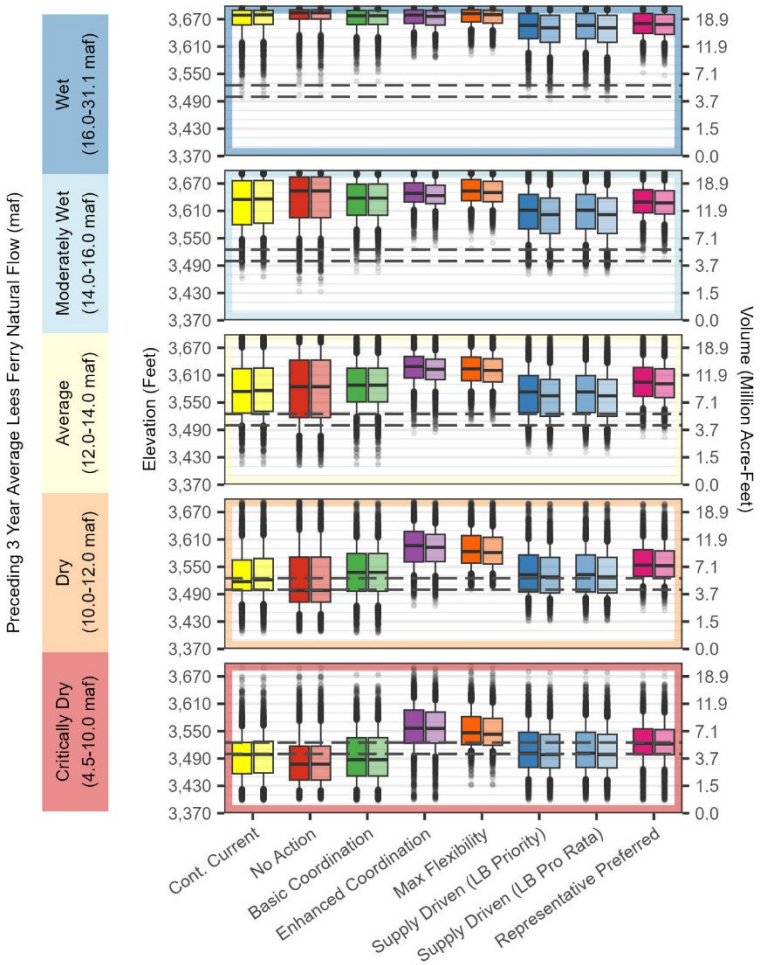
In the 'conservation-off' results, there are no mechanisms for the storage or delivery of newly conserved water. Furthermore, delivery of pre-2027 conservation is turned off for all the alternatives and the CCS Comparative Baseline.

Figure TA 3-16 presents conditional boxplots of how conservation activity affects Lake Powell EOWY elevations (feet). In each boxplot pair, conservation activity is on in the left box (black outline with darker shading) and off in the right box (gray outline with lighter shading). See **Table TA 3-9** at the end of this TA for the full statistical summary.

Across all hydrologic flow categories, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have higher median Lake Powell elevations when conservation is on (left box) compared to when it is off (right box), with

differences ranging from 0.5 to 9.8 feet. Additionally, across all flow categories, the 25th-75th percentiles for these alternatives shift upward when conservation is on compared to when it is off.

Figure TA 3-16
Impacts of Modeling Assumptions for Conservation Activity on End of Water Year Elevations (Feet) at Lake Powell



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

For the No Action and Basic Coordination Alternatives, the 25th-75th percentile elevations are very similar when comparing conservation activity on and conservation activity off across all flow categories.

The CCS Comparative Baseline has lower 25th-75th percentile elevations across all flow categories when conservation is on compared to when it is off, which differs from all alternatives. In the Average Flow Category and the Dry Flow Category, the CCS Comparative Baseline has lower median elevations in Lake Powell when conservation activity is on by 2.1 feet and 4.0 feet,

respectively; for the other flow categories, the CCS Comparative Baseline has very similar medians for both conservation activity on and conservation activity off.

In the Dry Flow Category, with conservation activity on, the median Lake Powell elevation for the Representative Preferred Alternative is 3,554 feet (1.2 feet higher than with conservation activity off). In the Critically Dry Flow Category, with conservation activity on, the median Lake Powell elevation for the Representative Preferred Alternative is 3,523 feet (0.8 feet higher than with conservation activity off). The variability is similar with conservation on and off in both the Dry and Critically Dry Flow Categories.

Figure TA 3-17 presents conditional boxplots of how conservation activity affects Lake Mead EOCY elevations (feet) and storage volumes. In each boxplot pair, conservation activity is on in the left box (black outline with darker shading) and off in the right box (gray outline with lighter shading). See **Table TA 3-10** at the end of this TA for the full statistical summary.

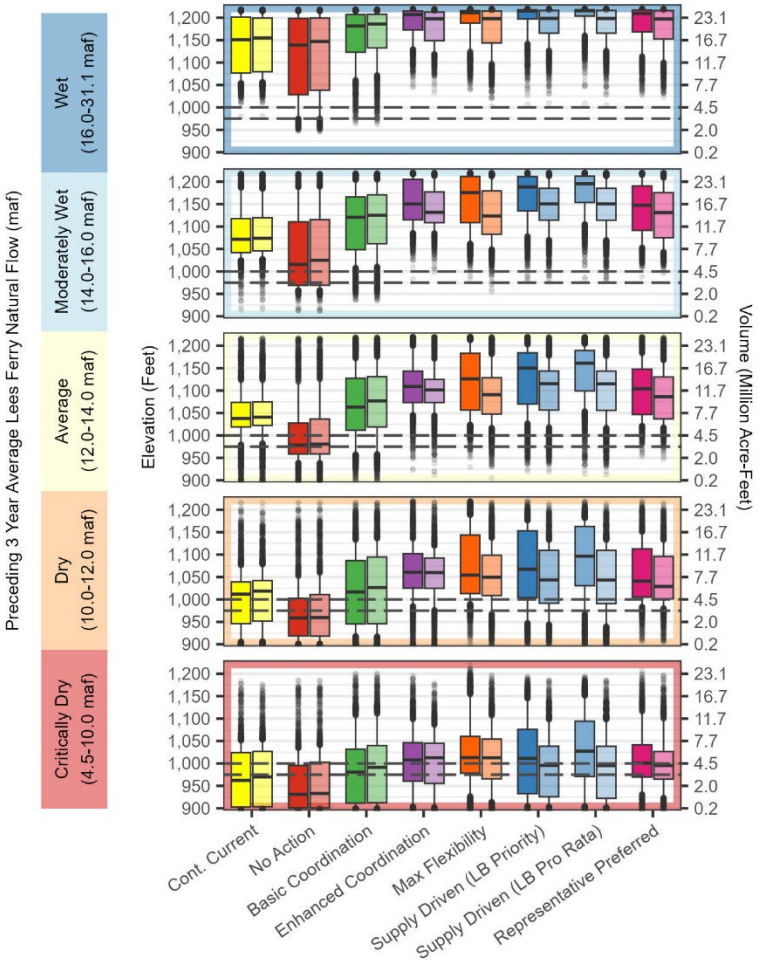
The Enhanced Coordination, Maximum Operational Flexibility, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have higher median Lake Mead elevations when conservation activity is on across all flow categories except the Critically Dry Flow Category. Within the Critically Dry Flow Category, only the Maximum Operational Flexibility and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives show higher median Lake Mead elevations when conservation is on. For these alternatives, the 25th-75th percentile elevations also shift upward when conservation is on across all hydrologic conditions, following the same general pattern as the median elevations. The CCS Comparative Baseline, the No Action Alternative and the Basic Coordination Alternative all have lower 25th-75th percentile elevations that shift downward when conservation is on, across all flow categories.

With respect to the critical elevation of 975 feet, the No Action Alternative falls below the critical threshold in almost 50 percent of years in the Average Flow Category for both conservation activity on and conservation activity off, while the CCS Comparative Baseline only falls below the threshold in more than 50 percent of years in the Critically Dry Flow Category for both conservation activity on and conservation activity off. With respect to the critical elevation of 1,000 feet, the No Action Alternative falls below the critical threshold between 25 and 50 percent of years in the Average Flow Category for both conservation activity on and conservation activity off and in about 75 percent of years in the Critically Dry Flow Category for both conservation activity on and conservation activity off. With respect to the critical elevation of 1,000 feet, the CCS Comparative Baseline falls below the critical threshold in fewer than 25 percent of years in the Average Flow Category for both conservation activity on and conservation activity off and in fewer than 75 percent of years in the Critically Dry Flow Category for both conservation activity on and conservation activity off.

In the Dry Flow Category, under the Representative Preferred Alternative the median Lake Mead elevation with conservation activity on is 1,041 feet (11.8 feet higher than with conservation activity off). Performance of the Representative Preferred Alternative in this category is most similar to the Basic Coordination Alternative but with 25th percentile values that are closer to the median (reduced variability) for both conservation activity on and off. In the Critically Dry Flow Category, under the Representative Preferred Alternative, the median Lake Mead elevation with conservation activity on

is 1,001 feet (5.6 feet higher than with conservation activity off). Performance of the Representative Preferred Alternative is again similar to the Basic Coordination Alternative, but with reduced variability for both conservation activity on and off.

Figure TA 3-17
Impacts of Modeling Assumptions for Conservation Activity on EOCY Elevations and Storage Volumes for Lake Mead



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

With respect to the critical elevation of 975 feet, the Representative Preferred Alternative falls below the critical threshold in less than 10 percent of years in the Dry Flow Category and more than 25 percent of years in the Critically Dry Flow Category, for both conservation activity on and conservation activity off. With respect to the critical elevation of 1,000 feet, the Representative Preferred Alternative falls below the critical threshold in about 25 percent of years in the Dry Flow Category and around 50 percent of years in the Critically Dry Flow Category for both conservation activity on and conservation activity off.

Lake Mohave and Lake Havasu

Lake Mohave and Lake Havasu are operated under an existing rule curve that determines specific target elevations at the end of each month (refer to **TA 6**, Water Quality). The existing rule curves were used in CRSS and applied to operations for all alternatives and the CCS Comparative Baseline.

Although inflows into Lake Mohave vary across alternatives due to differences in releases from Lake Mead, target elevations are maintained within the rule curve bounds. As a result, lake elevations are not affected by the different upstream operations occurring in the alternatives or the CCS Comparative Baseline.

Similarly, although inflows into Lake Havasu from upstream operations (Davis Dam releases) vary across alternatives, target elevations are maintained within the rule curve bounds. As a result, lake elevations are not affected by the different upstream operations occurring in the alternatives or the CCS Comparative Baseline.

TA 3.2.2 Issue 2: System Storage

Issue 2 addresses how operational activities would affect system storage. This was evaluated by comparing the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Combined System Storage at Lake Powell and Lake Mead
- Combined System Storage at CRSP reservoirs
- Combined System Storage at all seven reservoirs

Combined System Storage at Lake Powell and Lake Mead

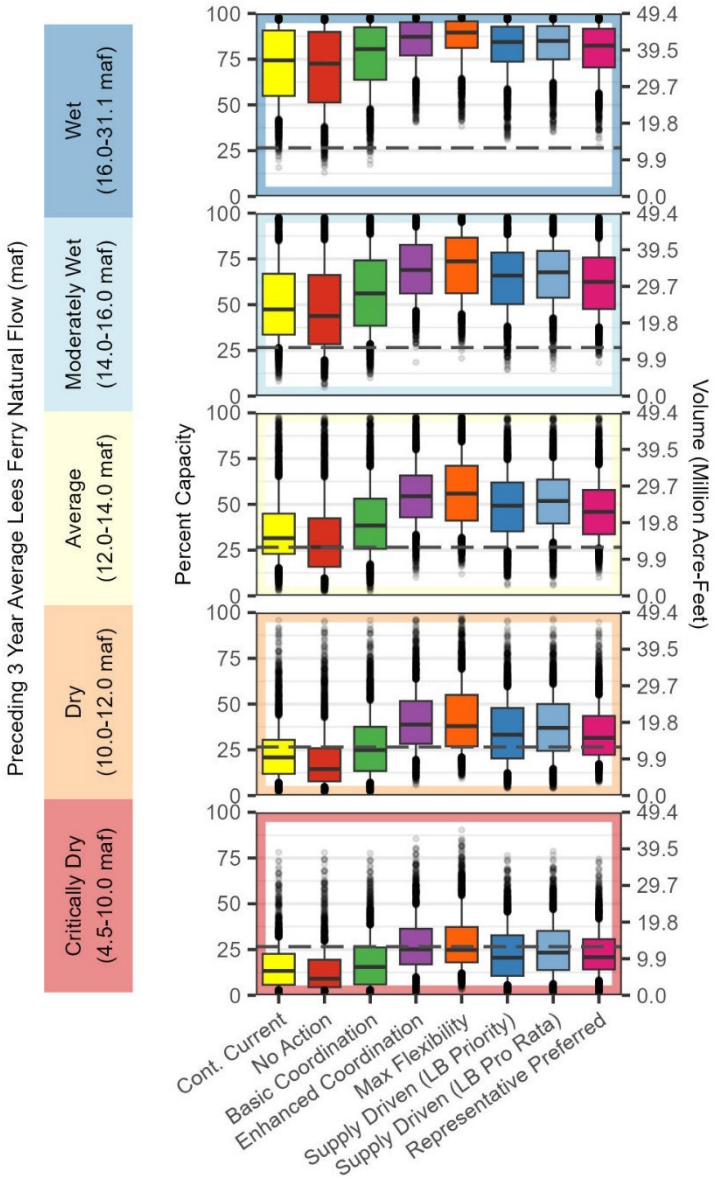
This section compares all alternatives and the CCS Comparative Baseline with respect to EOWY combined storage of Lake Powell and Lake Mead. Analysis of the combined storage of these two reservoirs provides insight into overall system conditions because their combined volume makes up about 85 percent of the volume in the major system reservoirs.[5] Excluding space allocated for surcharge and Flood Control, the live storage capacity at Lake Powell is 23.31 maf and 26.12 maf at Lake Mead, resulting in a maximum combined live storage of 49.43 maf.

Figure TA 3-18 presents conditional boxplots of EOWY combined storage in Lake Powell and Lake Mead, expressed as a percentage of total storage capacity. The vertical axis shows combined percent full on the left and volume of storage on the right. A threshold line indicates the lowest observed EOWY combined storage, which occurred in September 2022, at 26.55 percent full (equivalent to 13.1 maf). See **Table TA 3-11** at the end of this TA for the full statistical summary.

In the Average Flow Category, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives all have median Lake Powell and Lake Mead combined storage volumes above 50 percent of the total combined storage capacity. Fewer than 10 percent of modeled years (corresponding to the 10th percentile) for these action alternatives fall below the lowest observed EOWY storage reference of 26.55 percent. In terms of interquartile

[5] Specifically, Lake Powell and Lake Mead account for 85 percent of the live storage capacity of the seven largest reservoirs in the system (Flaming Gorge, Blue Mesa, Navajo, Powell, Mead, Mohave, and Havasu).

Figure TA 3-18
EOWY Powell and Mead Combined Storage[6]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

range, the Maximum Operational Flexibility Alternative shows the greatest variability, with the highest 75th percentile storage volume; the Enhanced Coordination Alternative has the least variability; and the Supply Driven Alternative (LB Pro Rata approach) has the lowest 25th percentile storage volume. By comparison, the CCS Comparative Baseline and the Basic Coordination and No

[6] Dashed reference line is historical EOWY minimum 26.55 percent in September 2022.

Action Alternatives have lower median storage volumes, at 32, 38, and 27 percent of total capacity, respectively. Under the CCS Comparative Baseline, more than 25 percent of years (corresponding to the 25th percentile), fall below the lowest observed EOWY storage reference of 26.55 percent. Under the No Action Alternative, almost 50 percent of years (corresponding to the 50th percentile) fall below the lowest observed EOWY storage reference of 26.55 percent.

In the Critically Dry Flow Category, the same general trends are observed. For the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata approach) Alternatives, about 50 percent of modeled years (corresponding to the 50th percentile) fall below the lowest observed EOWY storage reference of 26.55 percent. For the CCS Comparative Baseline and No Action and Basic Coordination Alternatives, more than 75 percent of years (corresponding to the 75th percentile) fall below this reference.

In the Dry Flow Category, the Representative Preferred Alternative has a median of 32 percent combined storage, with 25th and 75th percentiles of 22 and 44 percent combined storage, respectively. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median of 21 percent combined storage, with 25th and 75th percentiles of 14 and 31 percent combined storage. Under the Representative Preferred Alternative, more than 25 percent of years in the Dry Flow Category and nearly 75 percent of years in the Critically Dry Flow Category have combined storage below the lowest observed historical value of 26.55 percent.

Combined System Storage at CRSP Reservoirs

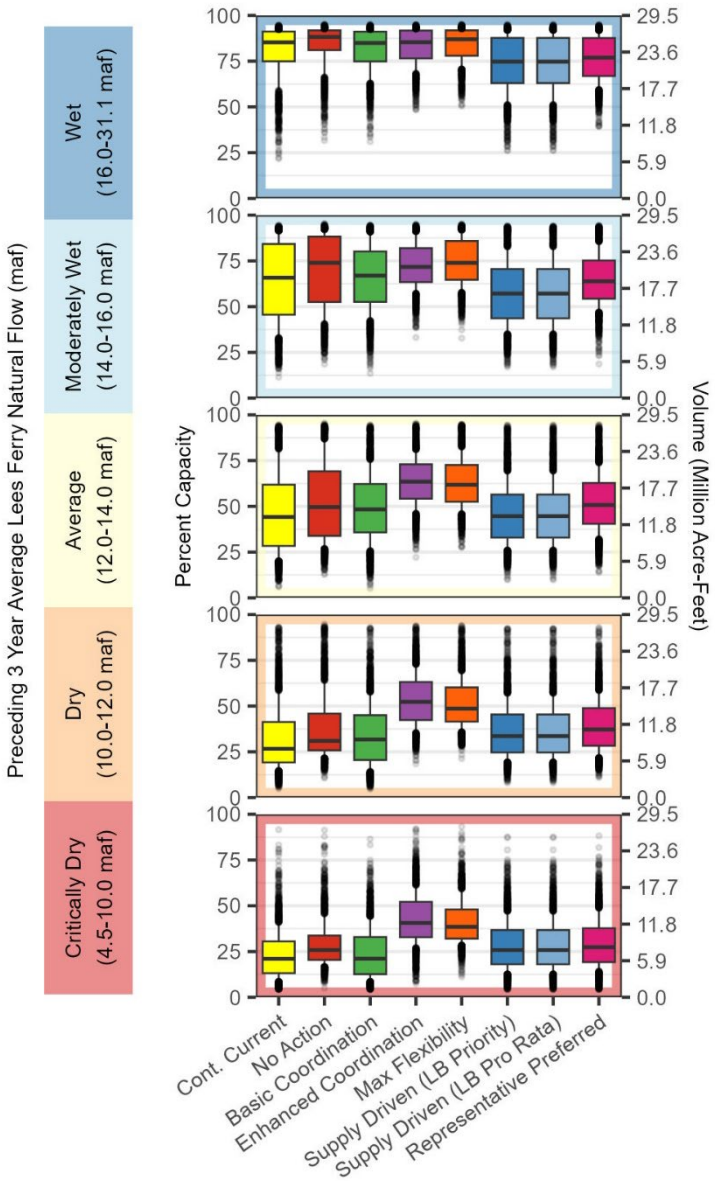
This section compares all alternatives and the CCS Comparative Baseline with respect to EOWY combined storage of the CRSP reservoirs, including Lake Powell and the CRSP UIUs—Flaming Gorge, Navajo, and Blue Mesa. Analysis of the combined storage provides insight into the system conditions at Lake Powell and the CRSP UIUs, and this volume is the criteria for Lake Powell releases in the Maximum Operational Flexibility Alternative. The CRSP UIU reservoirs can be operated in accordance with their respective RODs, subject to hydrologic conditions, to help protect infrastructure at Glen Canyon Dam.

Specifically, the CCS Comparative Baseline, along with the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, assume additional releases from the CRSP UIUs when Lake Powell is projected to, or physically falls below, elevation 3,525 feet. The CCS Comparative Baseline and Basic Coordination Alternative include additional releases from Flaming Gorge, Blue Mesa, and Navajo Reservoirs, while the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) assumes additional releases only from Flaming Gorge.

Excluding surcharge space, the total storage volume of the four CRSP reservoirs is approximately 29.5 maf, with Lake Powell accounting for approximately 80 percent. Because storage at the CRSP UIUs varies minimally across alternatives, most differences in performance are attributable to Lake Powell operations. Additionally, because transfers within the CRSP reservoirs, from the UIUs downstream to Lake Powell, do not change total combined storage, these intra-system balancing operations are not visible in the conditional box plots. Differences across alternatives are therefore driven primarily by Lake Powell operations, as described in Issue 1 above.

Figure TA 3-19 presents conditional boxplots of EOWY CRSP combined system storage, expressed as a percentage of total storage capacity. See **Table TA 3-12** at the end of this TA for the full statistical summary.

Figure TA 3-19
EOWY CRSP Combined Storage



The alternatives and the CCS Comparative Baseline generally perform similarly under the Wet Flow Category, except for the Supply Driven (both LB Priority and LB Pro Rata approaches) and the Representative Preferred Alternatives, which have the lowest median combined CRSP reservoir storage (as a percent of the total capacity). As flow categories become drier, combined CRSP reservoir storage decreases and differences between alternatives become more apparent.

In the Average Flow Category, the median EOWY CRSP combined storage values for the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are near 50 percent of the total capacity, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives have higher median storage values, at 63 percent and 62 percent, respectively. Among these alternatives, the Enhanced Coordination Alternative has the highest 75th percentile storage but the smallest interquartile range, reflecting higher upper-end storage with relatively lower variability. By comparison, the No Action Alternative has a similar 75th percentile and the largest interquartile range, indicating greater variability in combined CRSP storage.

In the Critically Dry Flow Category, median and interquartile range patterns shift as hydrologic conditions worsen. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have the highest median storage values (41 and 38 percent, respectively). The remainder of the alternatives and the CCS Comparative Baseline have similar medians (21 to 26 percent). Considering the 10th through 90th percentile values, the CCS Comparative Baseline and Basic Coordination Alternative result in the least CRSP combined storage. The No Action Alternative exhibits the least variability (interquartile range of 13 percent) followed by the Maximum Operational Flexibility Alternative (16 percent), while the Basic Coordination Alternative exhibits the most variability (20 percent).

In the Dry Flow Category for EOWY CRSP combined storage, the Representative Preferred Alternative has a median of 37 percent combined storage, with 25th and 75th percentiles ranging from 28 to 49 percent combined storage. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median of 27 percent combined storage, with 25th and 75th percentiles of 19 and 38 percent combined storage, respectively.

Combined System Storage at Seven-Reservoirs

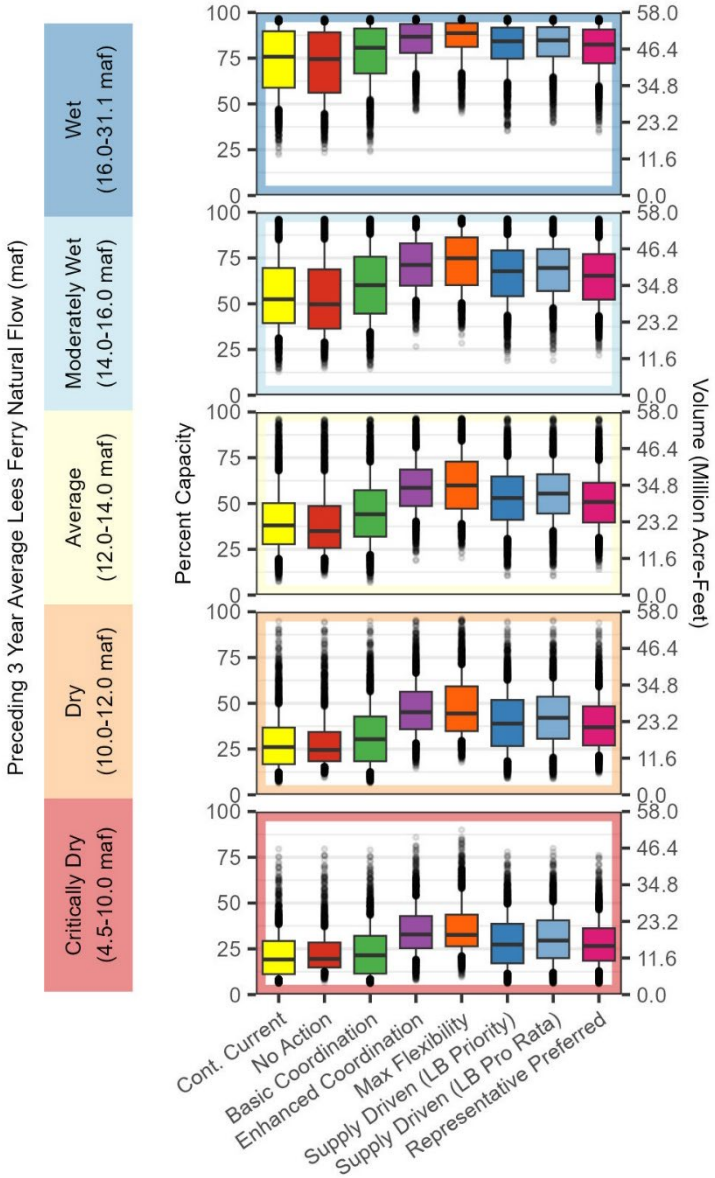
This section compares all alternatives and the CCS Comparative Baseline with respect to EOWY combined storage of Lake Powell, the three CRSP UIUs (Flaming Gorge, Navajo, and Blue Mesa), Lake Mead, Lake Mohave, and Lake Havasu (referred to herein as the seven-reservoir storage). Excluding space allocated for surcharge and Flood Control, the live storage capacity of these seven reservoirs is 58.01 maf, with Lake Powell and Lake Mead accounting for approximately 90 percent of the total system storage capacity.

Figure TA 3-20 presents conditional boxplots of EOWY combined storage for the seven reservoirs, expressed as a percentage of the total storage capacity. See **Table TA 3-13** at the end of this TA for the full statistical summary.

In the Average Flow Category, the Maximum Operational Flexibility Alternative exhibits the greatest median seven-reservoir storage (60 percent), followed closely by Enhanced Coordination (59 percent). The Maximum Operational Flexibility, Enhanced Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have median EOWY seven-reservoir storage above 50 percent of the total storage capacity. The Enhanced Coordination Alternative exhibits the least variability (interquartile range of 20 percent) while the Maximum Operational Flexibility exhibits the greatest variability (interquartile range of 26 percent). The Basic Coordination

and No Action Alternatives and the CCS Comparative Baseline have the lowest median seven-reservoir storage of 44 percent, 35 percent, and 38 percent, respectively. Likewise, they have the lowest 10th and 25th percentile seven-reservoir storage.

Figure TA 3-20
EOWY Seven-Reservoir Combined Storage



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

In the Critically Dry Flow Category, the order of medians and relationships across the alternatives and the CCS Comparative Baseline are generally similar to those in the Average Flow Category, but with notable reductions to storage volumes. The CCS Comparative Baseline and No Action

Alternative have the lowest median seven-reservoir storage (both with 19 percent), followed by the Basic Coordination Alternative (21 percent).

In the Dry Flow Category, the Representative Preferred Alternative has a median seven-reservoir storage of 37 percent, with 25th and 75th percentiles of 27 and 48 percent. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median of 27 percent combined storage, with 25th and 75th percentiles of 18 and 36 percent.

TA 3.2.3 Issue 3: Reservoir Releases

Issue 3 addresses how operational activities would affect reservoir releases. This was evaluated by comparing the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- WY Releases from Glen Canyon Dam
- 10-Year Releases from Glen Canyon Dam
- 10-Year Flows at Lee Ferry Compact Point
- CY Releases from Hoover Dam
- CY Releases from Davis Dam
- CY Releases from Parker Dam

Glen Canyon Dam

This section compares all alternatives and the CCS Comparative Baseline with respect to WY releases from Glen Canyon Dam at Lake Powell. Note that the performance of the LB Priority approach and the LB Pro Rata approach under the Supply Driven Alternative will not differ in Glen Canyon Dam releases because they use the same operation of Lake Powell.

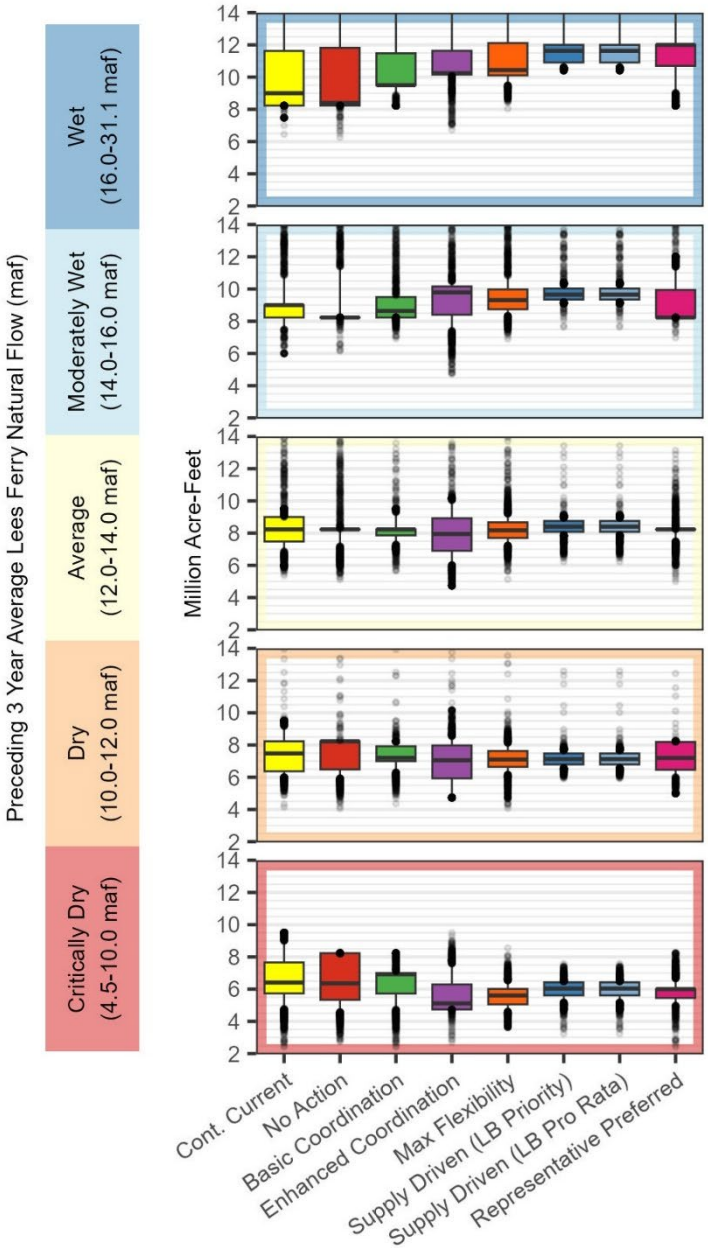
Figure TA 3-21 presents conditional boxplots of WY releases (maf) from Glen Canyon Dam. The y-axis has been truncated to facilitate easier comparison of the alternatives, see **Table TA 3-14** at the end of this TA for the full statistical summary.

In the Average Flow Category, the median annual Glen Canyon Dam releases for all alternatives and the CCS Comparative Baseline are between 7.95 maf (Enhanced Coordination) and 8.41 maf (Supply Driven [both LB Priority and LB Pro Rata approaches]). The Enhanced Coordination Alternative has the most variable release (interquartile range of 2.02 maf), followed by the CCS Comparative Baseline (interquartile range of 1.52 maf). The No Action and Representative Preferred Alternatives have the least variable release (interquartile range of 0 maf).

In the Critically Dry Flow Category, the No Action Alternative (6.36 maf), CCS Comparative Baseline (6.41 maf), and Basic Coordination Alternative (6.92 maf) have the largest median releases while the Enhanced Coordination (5.11 maf) and Maximum Operational Flexibility (5.61 maf) Alternatives have the lowest median releases. The No Action Alternative has the most variable releases (interquartile range of 2.90 maf) due to a large difference between the intended release (8.23 maf) and what is physically capable of being released due to infrastructure limitations below 3,490 feet.

In the Dry Flow Category for annual Glen Canyon Dam releases, the Representative Preferred Alternative has a median annual release of 7.20 maf, with 25th and 75th percentiles of 6.47 and 8.19 maf, respectively. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median annual release of 6.0 maf. The 25th and 75th percentiles are 5.45 and 6.0 maf. Representative Preferred releases under Critically Dry Hydrology are the least variable of all alternatives.

Figure TA 3-21
WY Releases from Glen Canyon Dam[7]

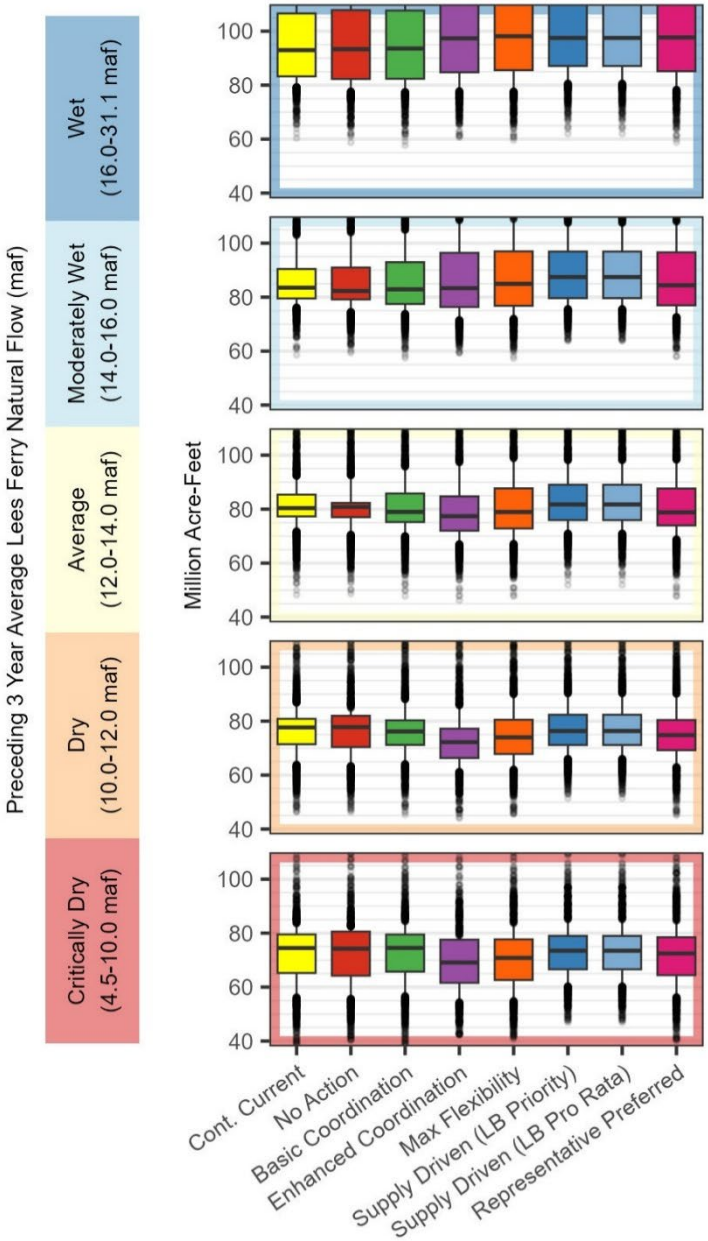


[7] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-14** for the full range of the data.

Glen Canyon Dam 10-Year Releases

Figure TA 3-22 presents conditional boxplots of cumulative 10-year releases from Glen Canyon Dam. The y-axis is truncated to enable easier comparison of alternatives. See **Table TA 3-15** at the end of this TA for the full statistical summary and full range of values.

Figure TA 3-22
10-Year Cumulative Releases from Glen Canyon Dam[8]



[8] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-15** for the full range of the data.

In the Average Flow Category, the median 10-year cumulative release ranges from 77.4 maf (Enhanced Coordination Alternative) to 81.7 maf (Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]). Considering the 25th percentile, the Enhanced Coordination Alternative still exhibits the smallest 10-year release (72.0 maf), but the CCS Comparative Baseline has the greatest 10-year release of 77.3 maf. All action alternatives display significant variability, with the Maximum Operational Flexibility Alternative having the largest interquartile range of 14.8 maf (25th and 75th percentiles of 72.8 and 87.7 maf, respectively). In contrast, the No Action Alternative and CCS Comparative Baseline are the least variable with interquartile ranges of 5.3 and 8.1 maf, respectively.

In the Critically Dry Flow Category, the Basic Coordination Alternative and CCS Comparative Baseline have the highest median release (both 74.5 maf), followed closely by the No Action Alternative (74.2 maf). The Enhanced Coordination Alternative has the lowest median release (69.1 maf). The No Action Alternative has the greatest variability in 10-year releases (interquartile range of 16.4 maf) followed by the Enhanced Coordination (16.0 maf) and Maximum Operational Flexibility Alternatives (15.1 maf). However, for the No Action Alternative, this variability is driven by infrastructure-constrained releases (Lake Powell elevations below 3,490 feet) while it is driven by annual releases that are highly responsive to hydrologic conditions in the Enhanced Coordination and Maximum Operation Flexibility Alternatives.

In the Dry Flow Category for 10-year cumulative releases from Glen Canyon Dam, the Representative Preferred Alternative has a median 10-year release of 74.8 maf, with 25th and 75th percentiles of 69.2 maf and 80.4 maf, respectively. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median 10-year release of 72.4 maf, with 25th and 75th percentiles of 64.4 maf and 78.5 maf, respectively.

Cumulative 10-Year Lee Ferry Flows

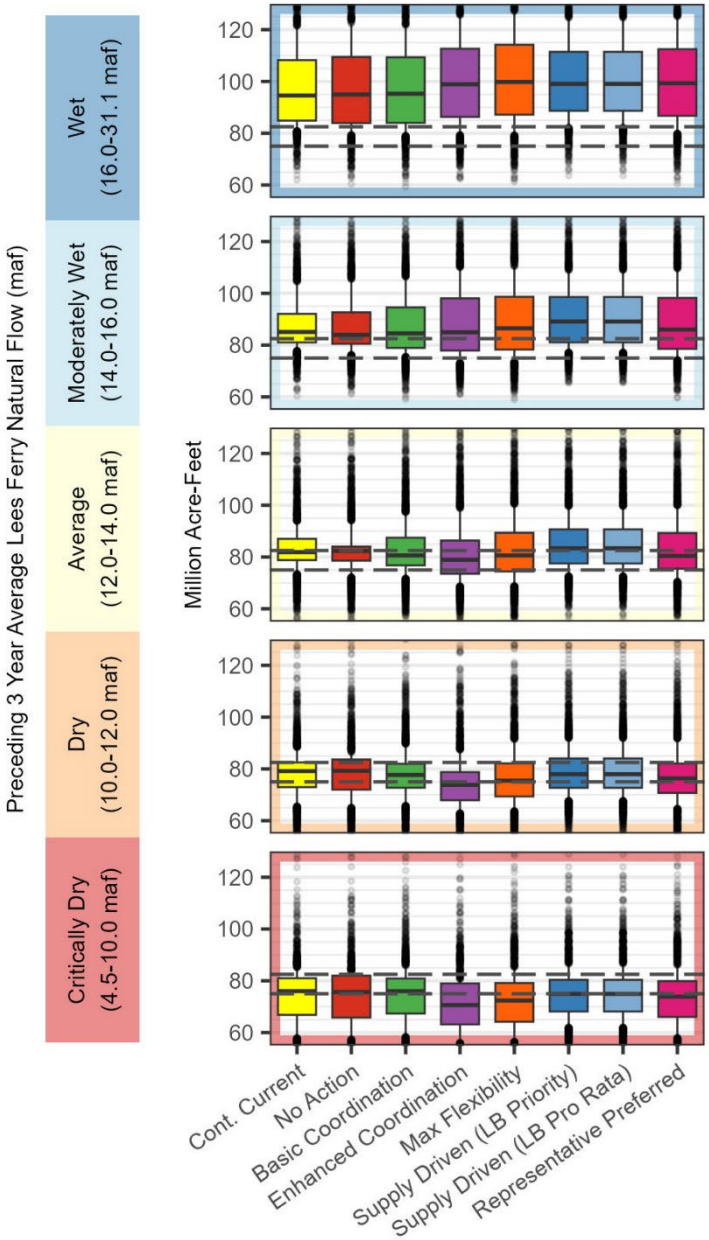
The Lee Ferry is the division point between the Upper Basin and the Lower Basin, as established by the 1922 Colorado River Compact. The Lee Ferry is located in Arizona, approximately 17 miles downstream of Glen Canyon Dam and approximately 1 mile downstream of the confluence with the Paria River. Refer to **Figure TA 3-2** in the Affected Environment Section for a map of the Lee Ferry.

Figure TA 3-23 presents conditional boxplots of cumulative 10-year Lee Ferry flow volumes (maf), with **Table TA 3-16** at the end of this TA providing the full statistical summary. In each flow category, 75.0 maf and 82.5 maf are shown with dashed lines; however, comparison of modeled output to these thresholds is discussed under the description of **Table TA 3-17** and **Table TA 3-18** and **Figure TA 3-24.** To facilitate easier comparison of alternatives, the y-axis is truncated.

In the Average Flow Category, the median Compact Point 10-year volume ranges from 78.9 maf (Enhanced Coordination Alternative) to 83.4 maf (Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]). Considering the 25th percentile, the Enhanced Coordination Alternative also exhibits the smallest Compact Point 10-year volume (73.5 maf), but the CCS Comparative Baseline has the greatest volume of 78.8 maf. All action alternatives display significant variability, with the Maximum Operational Flexibility Alternative having the largest interquartile range of 14.9

maf (25th and 75th percentiles of 74.4 and 89.4 maf, respectively). In contrast, the No Action Alternative and CCS Comparative Baseline are the least variable with interquartile ranges of 5.4 and 8.2 maf, respectively.

Figure TA 3-23
Compact Point 10-Year Volume[9]



In the Critically Dry Flow Category, the CCS Comparative Baseline and Basic Coordination Alternative have the highest median Compact Point 10-year volume (both 76.0 maf), followed

[9] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-16** for the full range of the data.

closely by the No Action Alternative (75.7 maf). The Enhanced Coordination Alternative has the lowest median 10-year Compact Point volume (70.6 maf). The No Action Alternative has the greatest variability in Compact Point 10-year volumes (interquartile range of 16.2 maf) followed by the Enhanced Coordination (15.8 maf) and Maximum Operational Flexibility Alternatives (15.0 maf). However, for the No Action Alternative, this variability is driven by infrastructure-constrained releases (Lake Powell elevations below 3,490 feet) while it is driven by annual releases that are highly responsive to hydrologic conditions in the Enhanced Coordination and Maximum Operation Flexibility Alternatives.

In the Dry Flow Category, the Representative Preferred Alternative has a median Compact Point 10-year volume of 76.4 maf, with 25th and 75th percentiles of 70.7 maf and 82.1 maf, respectively. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median Compact Point 10-year volume of 73.9 maf, with 25th and 75th percentiles of 66.0 maf and 79.9 maf, respectively.

Figure TA 3-24 presents the cumulative 10-year flow volume at the Compact Point relative to two different thresholds using two side-by-side conditional box plot panels. In each panel, the dashed line denotes the zero-difference threshold between the modeled Compact Point 10-year volume and the applicable threshold (75.0 maf in the left panel and 82.5 maf in the right panel). Positive values indicate Compact Point 10-year volumes greater than the threshold. The y-axis is truncated to facilitate easier comparison of the alternatives. Consult **Table TA 3-17** and **Table TA 3-18** for the full range of data.

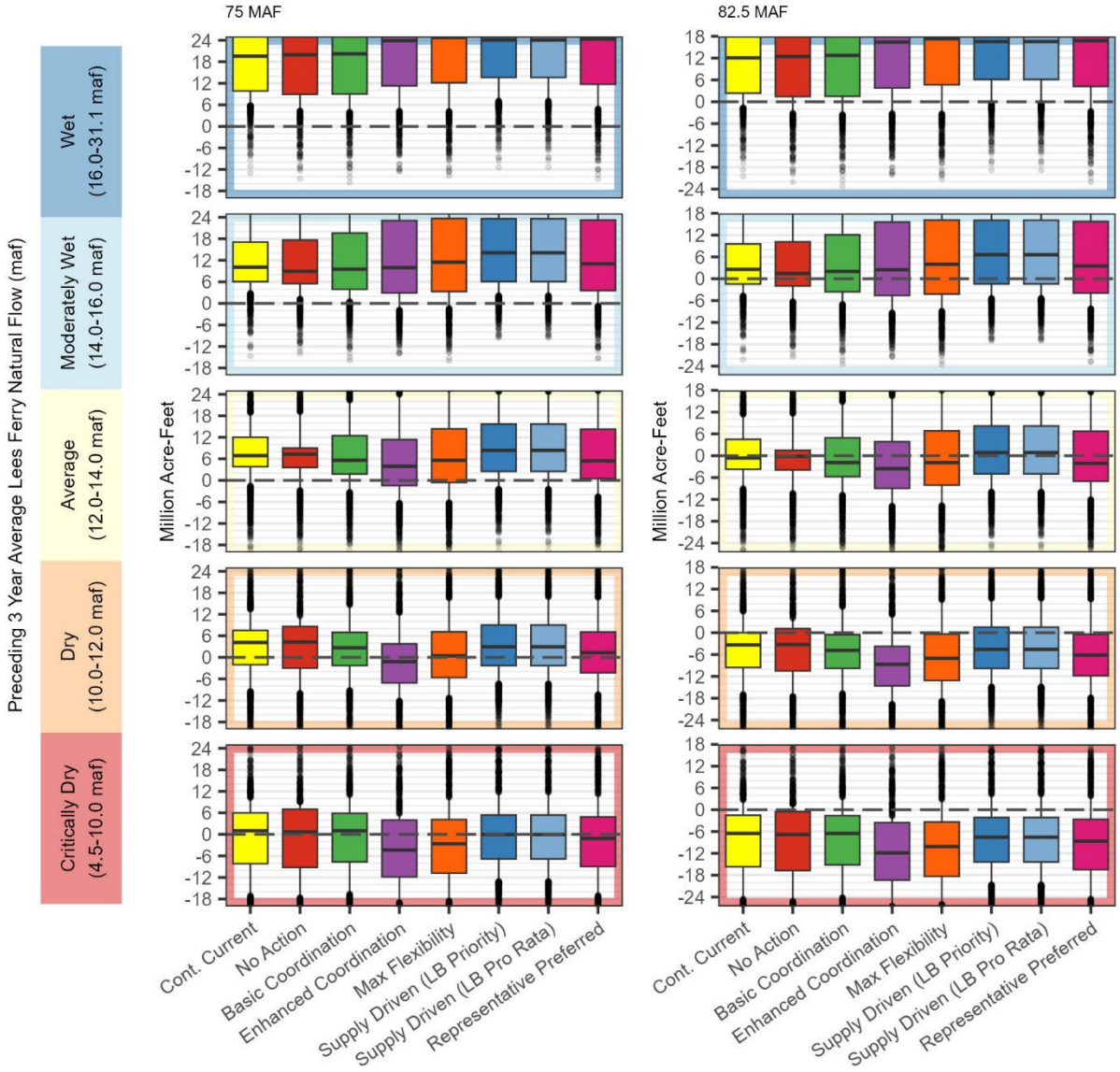
Under Average hydrology, considering the Compact Point 10-year volume **relative to 75.0 maf** (left column), the median values for all alternatives and the CCS Comparative Baseline are greater than zero, ranging from 3.9 maf (Enhanced Coordination Alternative) to 8.4 maf (Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]). Considering the 25th percentile, Enhanced Coordination (-1.5 maf) and Maximum Operational Flexibility (-0.6 maf) are the only alternatives with 10-year volumes less than 75.0 maf.

Under Average hydrology, considering the Compact Point 10-year volume **relative to 82.5 maf** (right column), the only alternative with a median value greater than zero is Supply Driven (both LB Priority and LB Pro Rata approaches) (0.9 maf). After Supply Driven (both LB Priority and LB Pro Rata approaches), the median values for the No Action Alternative and CCS Comparative Baseline are the least negative (i.e. have 10-year volumes closest to 82.5 maf), with values of -0.2 and -0.6 maf, respectively.

In Critically Dry hydrology, considering the Compact Point 10-year volume relative to 75.0 maf, only the CCS Comparative Baseline (1.0 maf), Basic Coordination Alternative (1.0 maf), and No Action Alternative (0.7 maf) have positive median values (i.e. 10-year volumes greater than 75.0 maf). The median for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is slightly negative (-0.06 maf). Relative to 82.5 maf, greater than 75 percent of years are negative (i.e. 10-year volumes less than 82.5 maf) for all alternatives and the CCS Comparative Baseline.

The variability across alternatives and under different hydrologic conditions are the same as discussed in **Figure TA 3-23**.

Figure TA 3-24[10]
Compact Point 10-Year Volume Relative to 75.0 maf and 82.5 maf



In the Dry Flow Category, the Representative Preferred Alternative has a median 10-year volume relative to 75.0 maf of 1.4 maf, indicating that over 50 percent of years under Dry conditions result in 10-year volumes above 75.0 maf. However, less than 25 percent of years exhibit 10-year volumes greater than 82.5 maf (i.e. the 75th percentile relative to 82.5 maf is negative). Under the Critically Dry Flow Category, fewer than 50 percent of years have 10-year volumes greater than 75.0 maf, while slightly more than 10 percent of years result in 10-year volumes greater than 82.5 maf.

[10] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-17** and **Table TA 3-18** for the full range of the data.

Hoover Dam

This section compares all the alternatives and the CCS Comparative Baseline with respect to CY releases from Hoover Dam at Lake Mead.

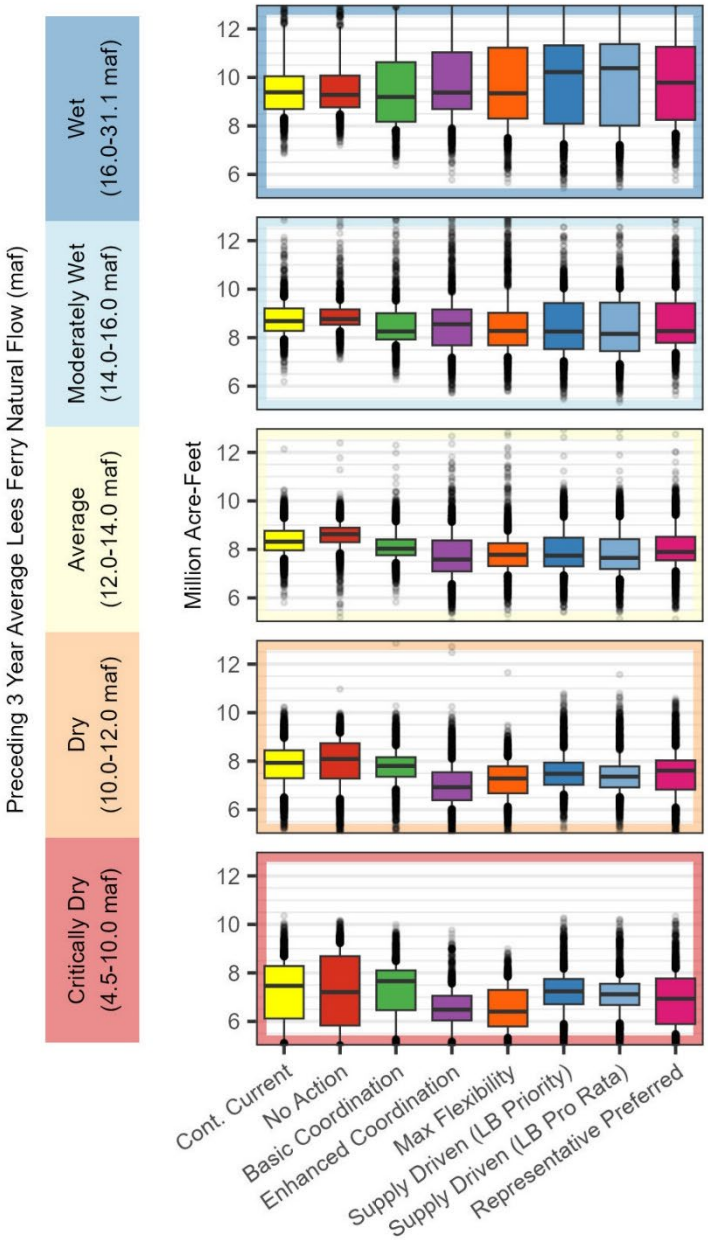
Figure TA 3-25 presents conditional boxplots of CY releases (maf) from Hoover Dam. The range of releases has been truncated to facilitate comparison of the alternatives, see **Table TA 3-19** at the end of this TA for the full range of data.

In the Average Flow Category, the median CY releases from Hoover Dam range from 7.58 maf, under the Enhanced Coordination Alternative, to 8.63 maf, under the No Action Alternative. The median releases for the No Action and Basic Coordination Alternatives and the CCS Comparative Baseline are all above 8.0 maf, while the median releases for other alternatives are all less than 8.0 maf. The No Action and Basic Coordination Alternatives have the least variable releases, with interquartile ranges of 0.60 and 0.65 maf, respectively. The Supply Driven (LB Priority approach), Supply Driven (LB Pro Rata approach), and Enhanced Coordination Alternatives have the greatest variability, with interquartile ranges of 1.18, 1.23 and 1.27 maf, respectively.

In the Critically Dry Flow Category, all alternatives except Enhanced Coordination and Maximum Operational Flexibility Alternatives have median releases between 7.12 maf (Supply Driven [LB Pro Rata approach]) and 7.66 maf (Basic Coordination). Maximum Operational Flexibility and Enhanced Coordination have median releases of 6.40 and 6.48 maf, respectively. All alternatives except Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) have increased variability in Critically Dry conditions compared to Average conditions, with interquartile ranges between 1.51 maf (Maximum Operational Flexibility) and 2.86 maf (No Action Alternative). The Enhanced Coordination (1.02 maf), Supply Driven (LB Priority approach) (1.04 maf), and Supply Driven (LB Pro Rata approach) (0.88 maf) Alternatives have less variable releases (i.e. smaller interquartile ranges).

The Representative Preferred Alternative is roughly in the middle of the other alternatives and CCS Comparative Baseline, in terms of both median releases and variability in releases (except in Critically Dry where it is more variable). In the Dry Flow Category, the median release is 7.61 maf with an interquartile range of 1.20 maf (25th and 75th percentiles of 6.83 and 8.03 maf). In the Critically Dry Flow Category, the median release is 6.94 maf with an interquartile range of 1.88 maf (25th and 75th percentiles of 5.89 and 7.77 maf).

Figure TA 3-25
CY Releases from Hoover Dam[11]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

[11] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-19** for the full range of the data.

Davis Dam

Releases from Davis Dam, at Lake Mohave, are based on target elevations defined by the existing rule curve (refer to **TA 6**, Water Quality). Inflows into Lake Mohave vary across alternatives, and because elevations are kept to the range determined by the rule curve, releases from Davis Dam subsequently vary across alternatives.

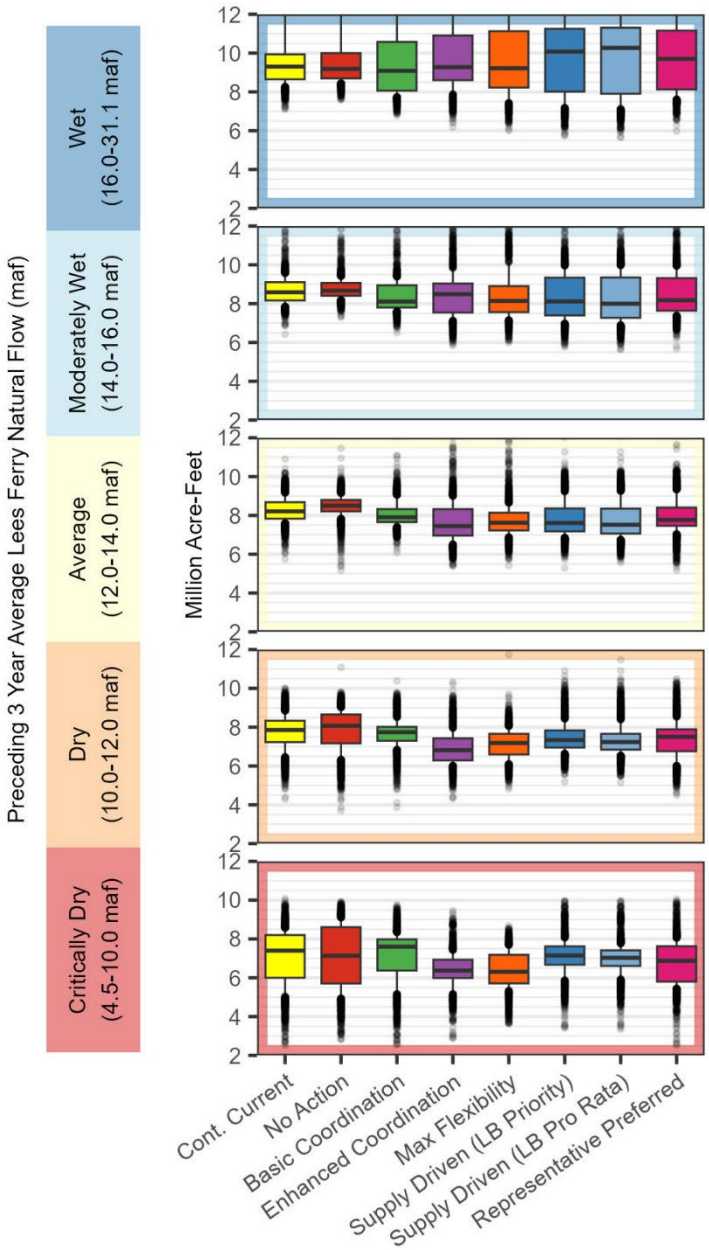
Figure TA 3-26 presents conditional boxplots of CY releases from Davis Dam. The range of releases has been truncated to facilitate comparisons of alternatives, see **Table TA 3-20** at the end of this TA for the full statistical summary and full range of values.

In the Average Flow Category, the median CY releases from Davis Dam range from 7.4 maf (Enhanced Coordination) to 8.5 maf (No Action Alternative). The median release for the CCS Comparative Baseline is 8.2 maf and for the Basic Coordination Alternative is 7.9 maf. Meanwhile, the median releases for the Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are closer to the median release under Enhanced Coordination (at 7.6 maf, 7.6 maf, and 7.5 maf, respectively). The No Action and Basic Coordination Alternatives have the least variability (interquartile ranges of 0.6 and 0.7 maf) while the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have the most (interquartile ranges of 1.4 and 1.3 maf).

In the Critically Dry Flow Category, the median CY releases from Davis Dam range from 6.3 maf (Maximum Operational Flexibility Alternative) to 7.6 maf (Basic Coordination Alternative). The median for the Enhanced Coordination Alternative (6.4 maf) is similar to the Maximum Operational Flexibility Alternative, although the Maximum Operational Flexibility Alternative exhibits greater variability. The Supply Driven (both LB Priority and LB Pro Rata approaches) and the Representative Preferred Alternatives have median releases greater than the Maximum Operational Flexibility and Enhanced Coordination Alternatives but less than the Basic Coordination Alternative and the CCS Comparative Baseline. The Supply Driven (LB Pro Rata approach), Enhanced Coordination, and Supply Driven (LB Priority approach) Alternatives exhibit the least variability (interquartile ranges of 0.8, 0.9, and 0.9 maf) while the CCS Comparative Baseline and No Action Alternative exhibit the greatest variability (interquartile ranges of 2.2 and 2.9 maf).

In the Dry Flow Category, the Representative Preferred Alternative has a median release of 7.5 maf, which is roughly in the middle compared to the other alternatives. However, it has the third greatest variability (interquartile range of 1.1 maf), behind only the No Action and Basic Coordination Alternatives. In the Critically Dry Flow Category, the median release is 6.9 maf and the interquartile range is 1.8 maf, both of which are roughly in the middle compared to other alternatives.

Figure TA 3-26
CY Releases from Davis Dam[12]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

[12] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-20** for the full range of the data.

Parker Dam

Releases from Parker Dam, at Lake Havasu, are based on target elevations defined by the existing rule curve (refer to **TA 6**, Water Quality). Inflows into Lake Havasu vary across alternatives, and because elevations are kept to the range determined by the rule curve, releases from Parker Dam subsequently vary across alternatives.

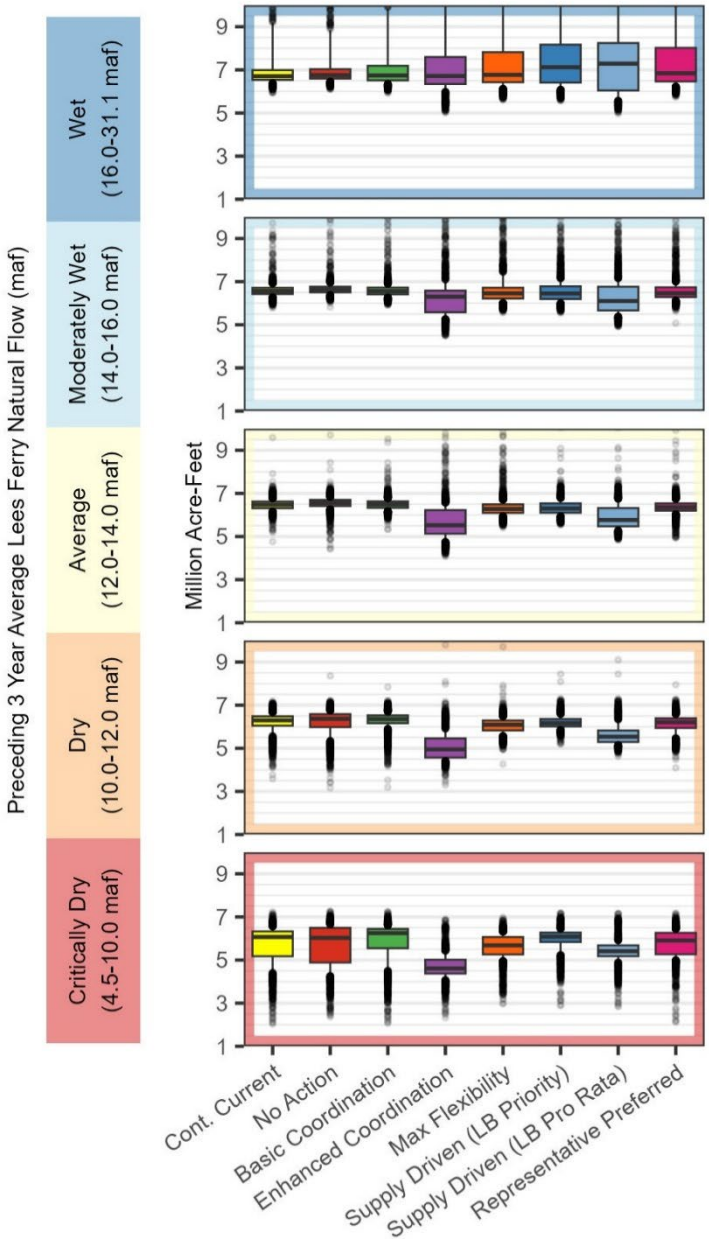
Figure TA 3-27 presents conditional boxplots of CY releases from Parker Dam. The range of releases is truncated to facilitate comparisons between the alternatives, see **Table TA 3-21** at the end of this TA for the full statistical summary and full range of values.

In the Average Flow Category, all alternatives except the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have median releases between 6.3 and 6.6 maf. The Enhanced Coordination (5.5 maf) and Supply Driven (LB Pro Rata approach) (5.8 maf) Alternatives have notably lower median releases due to pro rata-based distribution of shortages. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives also have the greatest variability (interquartile ranges of 1.1 and 0.8 maf, respectively), whereas the other alternatives have interquartile ranges between 0.3 and 0.4 maf.

As conditions become drier, median releases decrease for all alternatives and variability increases for all alternatives except the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. In the Critically Dry Flow Category, the Enhanced Coordination (4.6 maf), Supply Driven (LB Pro Rata approach) (5.4 maf), and Maximum Operational Flexibility (5.7 maf) Alternatives have the lowest median releases. The remaining alternatives and the CCS Comparative Baseline have higher and similar releases between 6.0 and 6.3 maf. When comparing the Critically Dry to Average Flow Category, most alternatives have greater variability in releases except for the Enhanced Coordination (interquartile range decreases from 1.1 maf to 0.6 maf), Supply Driven (LB Pro Rata approach) (decreases from 0.8 to 0.5 maf), and Supply Driven (LB Priority approach) Alternatives (remains 0.4 maf).

The Representative Preferred Alternative exhibits median releases and release variability similar to most alternatives. In the Dry Flow Category, the median release is 6.2 maf with 25th and 75th percentiles of 5.9 and 6.4 maf (interquartile range of 0.5 maf). Under the Critically Dry Flow Category, the median release is 5.9 maf with 25th and 75th percentiles of 5.3 and 6.3 maf (interquartile range of 1.0 maf).

Figure TA 3-27
CY Releases from Parker Dam[13]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

[13] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-21** for the full range of the data.

TA 3.2.4 Issue 4: River Flows

Issue 4 addresses how operational activities would affect river flows. This was evaluated by comparing the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Annual Colorado River flows below Glen Canyon Dam
- Annual Colorado River flows below Hoover Dam
- Annual Colorado River flows below Davis Dam
- Annual Colorado River flows below Parker Dam
- Annual Colorado River flows at Imperial Dam
- Annual Colorado River flow below Imperial Dam
- Annual Colorado River flow below Morelos Diversion Dam

The conclusions in this section are drawn from three-year average natural flow model outputs and are framed using five flow categories. The conditional box plots show the distribution of river flows (y-axis) over the full analysis period relative to each alternative (x-axis).

Reach 1: Glen Canyon Dam to Lake Mead

This reach of the river (between Glen Canyon Dam and Lake Mead) extends for 292 miles through narrow canyons, including GCNP. River flows in this reach primarily consist of controlled releases from Glen Canyon Dam at Lake Powell. Refer to Issue 3 for the analysis of WY releases and the 10-year cumulative releases from Glen Canyon Dam for the No Action Alternative, CCS Comparative Baseline, and action alternatives. While the results of CRSS analysis are on an annual basis, monthly releases from Lake Powell at Glen Canyon Dam meet the 2016 LTEMP ROD (Reclamation 2016) minimum flows. Reclamation has the option to conduct high flow experiment releases from Glen Canyon Dam under certain conditions to reduce sediment deposition, which usually occurs in durations ranging from 60 hours to 10 days. Refer to **TA 5**, Geomorphology and Sediment, and **TA 8**, Biological Resources – Fish and Other Aquatic Species, for the analysis of high flow experiment flows from Glen Canyon Dam.

This reach also includes contributions from the Paria River and Little Colorado River, two perennial tributaries that discharge to the Colorado River between Glen Canyon Dam and Lake Mead. Based on historical USGS gage data, inflows from the Paria River and Little Colorado River make up approximately three percent of the total flow in this reach of the Colorado River (USGS 2025a). From 1906 to 2005, the annual inflow of the Paria River averaged 21.0 kafy and the Little Colorado River inflow averaged 180.0 kafy. Since 2007, the annual inflow from the Paria River averaged 17.0 kafy, and the Little Colorado River inflow averaged 274.0 kafy. Inflows from the Paria River and Little Colorado River were modeled in CRSS as the same across alternatives.

Relating back to the Issue 3 analysis for Glen Canyon Dam, in the Average Flow Category, the median WY releases from Glen Canyon Dam are: 8.41 maf under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), 8.23 maf under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, 8.17 maf under the Maximum Operational Flexibility Alternative, 7.95 maf under the Enhanced Coordination Alternative, and 8.23 maf under

the Representative Preferred Alternative. The historic combined inflows from the Paria River and the Little Colorado River (291.0 kaf combined) are approximately 3.5 percent to 3.7 percent of these modeled Average Flow Category median Glen Canyon Dam releases.

Reach 2: Hoover Dam to Lake Mohave

This reach of the river (starting from the Hoover Dam at Lake Mead) is 67 miles long and flows through Pyramid Canyon, El Dorado Canyon, and Black Canyon. Lake Mohave is on the downstream end of the reach, and it acts hydraulically like a tailwater to Hoover Dam. River flows in this reach primarily consist of releases from Hoover Dam with small contribution from tributary inflows. According to the 2007 Final EIS, tributary inflows, mostly from side washes, comprise less than 1 percent of the total annual flow (Reclamation 2007a). CRSS modeling of flows in this reach do not account for tributary inflows and reflect only releases from Hoover Dam.

Below is brief summary of the modeling results presented in Issue 3 based on CY releases from Hoover Dam. For modeling results and an in-depth discussion, refer to **Table TA 3-19** and **Figure TA 3-25**.

In the Average Flow Category, the median annual flow volumes for the No Action Alternative, Basic Coordination Alternative, and the CCS Comparative Baseline range from 8.03 to 8.63 maf. The remaining alternatives range from 7.58 maf (Enhanced Coordination) to 7.89 maf (Representative Preferred). In the Critically Dry Flow Category, median values decrease, with the smallest values being 6.40 maf (Maximum Operational Flexibility) and 6.48 maf (Enhanced Coordination) and the largest values being 7.47 maf (CCS Comparative Baseline) and 7.66 maf (Basic Coordination). The Representative Preferred Alternative generally results in annual volumes in the middle compared to other alternatives and the CCS Comparative Baseline.

Reach 3: Davis Dam to Lake Havasu

This reach of the Colorado River (starting from Davis Dam at Lake Mohave) is 84 miles long and forms Lake Havasu. River flows in this reach are mostly comprised of releases from Davis Dam and tributary inflow from the Bill Williams River.

Inflows from the Bill Williams River discharge directly into Lake Havasu and are regulated by the USACE operations of Alamo Dam. From 1906 to 2007, the annual inflow averaged 102,000 af. From 2008 to 2022 the annual inflow averaged 105,000 af (USGS 2025b).

Releases from Davis Dam are the variable that would differ between alternatives, so they have been used for comparison. Below, a brief summary of CY releases from Davis Dam are provided. For modeling results and in-depth discussion, refer to **Table TA 3-20** and **Figure TA 3-26**.

In the Average Flow Category, the Basic Coordination Alternative, CCS Comparative Baseline, and No Action Alternative have the largest annual volumes of 7.9, 8.2, and 8.5 maf. The remaining alternatives range from 7.4 maf (Enhanced Coordination) to 7.8 maf (Representative Preferred). In the Critically Dry Flow Category, median values decrease, with the smallest values being 6.3 maf (Maximum Operational Flexibility) and 6.4 maf (Enhanced Coordination) and the largest values being 7.4 maf (CCS Comparative Baseline) and 7.6 maf (Basic Coordination). The Representative

Preferred Alternative generally results in annual volumes in the middle compared to other alternatives and the CCS Comparative Baseline.

Reach 4: Parker Dam to Cibola Gage

This reach of the river (starting from Parker Dam at Lake Havasu) is 105 miles long and goes to Reclamation's Cibola Gage. Flows in this reach primarily consist of releases from Parker Dam. Two major diversion dams are located in this reach of the river: Headgate Rock Dam and Palo Verde Diversion Dam. The impoundments of these dams are used to facilitate the diversion of water for the Colorado River Indian Tribes and Palo Verde Irrigation District.

The analysis of flows for this reach is based on CY release volumes from Parker Dam. A brief summary is provided below. For modeling results and in-depth discussion, refer to Issue 3, **Table TA 3-21** and **Figure TA 3-27**.

In the Average Flow Category, all alternatives except Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have median releases between 6.3 and 6.6 maf. The Enhanced Coordination (5.5 maf) and Supply Driven (LB Pro Rata approach) (5.8 maf) Alternatives have notably lower median releases due to pro rata-based distribution of shortages. As conditions become drier, median releases decrease for all alternatives. In the Critically Dry Flow Category, the Enhanced Coordination (4.6 maf), Supply Driven (LB Pro Rata approach) (5.4 maf), and Maximum Operational Flexibility (5.7 maf) Alternatives have the lowest median releases. The remaining alternatives and the CCS Comparative Baseline have higher and similar releases between 5.9 and 6.3 maf. The Representative Preferred Alternative has annual volumes similar to other alternatives besides the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which are notably lower.

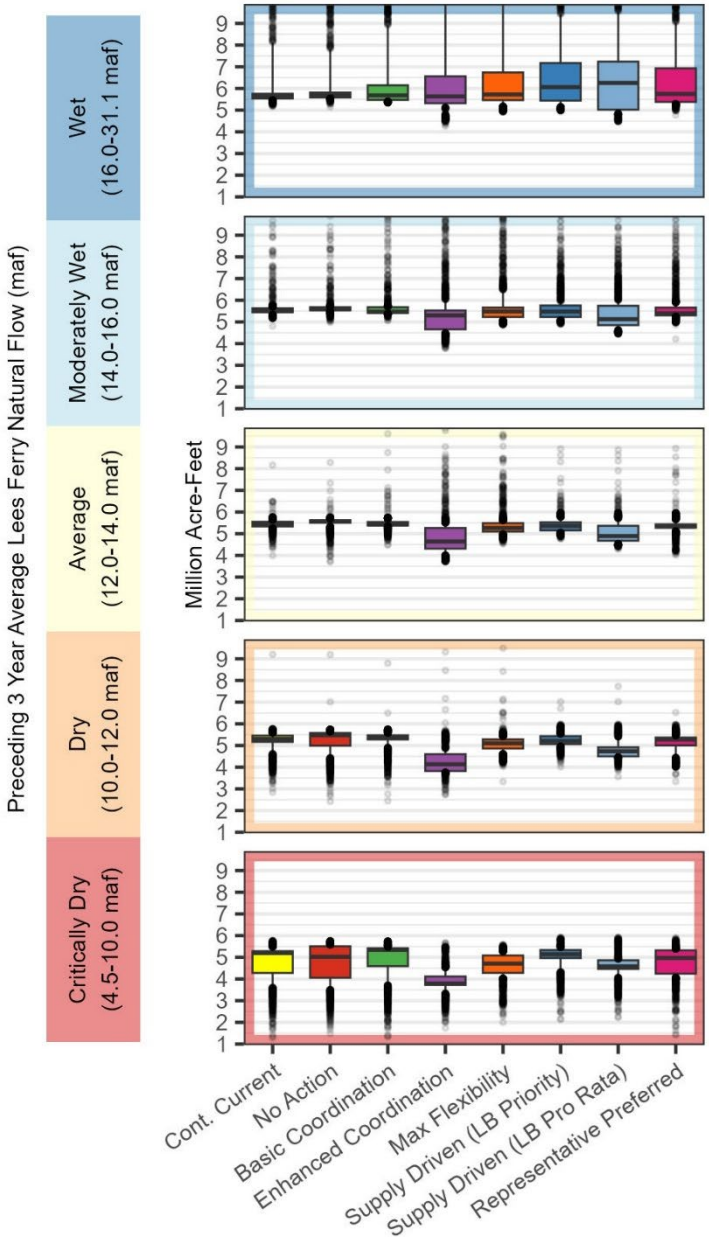
Reach 5: Cibola Gage to Imperial Dam

This reach of the river (starting from the Cibola Gage) is 38 miles long and is bounded on the downstream end by Imperial Dam at Imperial Reservoir. Flows in this reach consist primarily of releases from Parker Dam but are impacted by diversions and return flows. The Imperial Dam impoundment in this reach operates at a nearly constant elevation to meet water delivery requirements.

Figure TA 3-28 presents conditional boxplots of annual flow volume at Imperial Dam. The range of volumes is truncated at the high end to facilitate comparisons between alternatives, see **Table TA 3-22** at the end of this TA for the full statistical summary and full range of values.

In the Average Flow Category, most alternatives and the CCS Comparative Baseline have a median volume between 5.3 and 5.6 maf. The exceptions are the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which have smaller median volumes of 4.6 and 4.9 maf, respectively. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives are also distinct in that they have greater variability (interquartile ranges of 1.0 maf and 0.7 maf) compared to other alternatives and the CCS Comparative Baseline (interquartile ranges between 0.1 and 0.4 maf). These differences are due to the pro rata-based shortage distributions in the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives.

Figure TA 3-28
Annual Flow Volume at Imperial Dam[14]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

As hydrology becomes drier, all alternatives and the CCS Comparative Baseline show smaller annual flow volumes. In the Critically Dry Flow Category, most alternatives and the CCS Comparative Baseline have a median volume between 5.0 and 5.3 maf. However, the Enhanced Coordination (3.8

[14] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-22** for the full range of the data.

maf), Supply Driven (LB Pro Rata approach) (4.6 maf), and Maximum Operational Flexibility (4.7 maf) Alternatives have noticeably smaller annual volumes. The CCS Comparative Baseline, No Action Alternative, and Basic Coordination Alternative show greater variability (i.e. larger interquartile ranges) in the Critically Dry Flow Category compared to the Average Flow Category, likely due to dead pool-related delivery reductions (see **Figures TA 4-1** and **TA 4-2** in **TA 4**, Water Deliveries). The Maximum Operational Flexibility and Representative Preferred Alternatives also show greater variability, but likely due to increased shortages (not dead pool-related delivery reductions - see **Figures TA 4-1** and **TA 4-2** in **TA 4**, Water Deliveries). Variability decreases for the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives and remains about the same for the Supply Driven Alternative (LB Priority approach).

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: a median value of 5.3 maf (tied with CCS Comparative Baseline and third largest behind No Action and Basic Coordination Alternatives) and an interquartile range of 0.4 maf (third largest variability after the Enhanced Coordination and No Action Alternatives). In the Critically Dry Flow Category, the Representative Preferred Alternative exhibits the following outcomes: a median value of 5.0 maf (in the middle of the range of medians) and an interquartile range of 1.1 maf (second largest variability after the No Action Alternative).

Reach 6: Imperial Dam to NIB

This reach of the river (starting from the Imperial Dam) is 26 miles long and is bounded on the downstream end by NIB between the U.S. and Mexico. Flows in this reach primarily consist of releases from Imperial Dam to make delivery requirements. Flows in this reach also include water leaked from the AAC's sluiceway gates and return flow from Imperial Dam diversions.

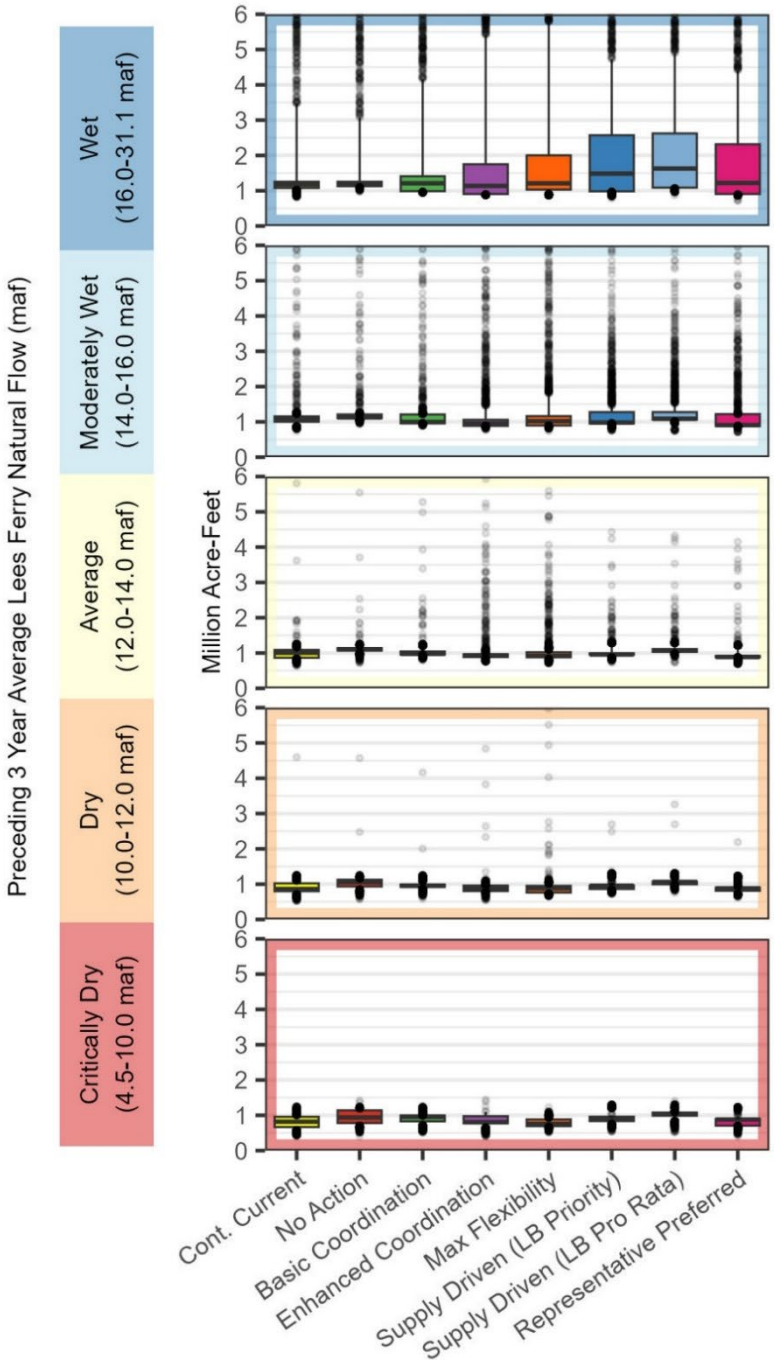
Figure TA 3-29 presents conditional boxplots of annual flow volume below Imperial Dam. The range of volumes is truncated at the high end to facilitate comparisons between alternatives, see **Table TA 3-23** at the end of this TA for the full statistical summary and full range of values.

In the Average Flow Category, the median annual flow volumes below Imperial Dam range from 0.9 maf (Maximum Operational Flexibility and Enhanced Coordination Alternatives) to 1.1 maf (No Action and Supply Driven [LB Pro Rata] Alternatives, and CCS Comparative Baseline). The CCS Comparative Baseline and all action alternatives have low variability in the Average Flow Category, with interquartile ranges between 34 and 221 kaf. Although rare, less than 10 percent of years have large volumes with maximums between 8.5 and 15.6 maf due to Flood Control operations.

In the Critically Dry Flow Category, the median annual flow volumes range from 0.8 maf (CCS Comparative Baseline, Enhanced Coordination Alternative, and Maximum Operational Flexibility Alternatives), to 1.0 maf (Supply Driven Alternative [LB Pro Rata approach] and Basic Coordination Alternatives). Variability in terms of interquartile range and outliers is low.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median volume is 0.9 maf and the interquartile range is 88 kaf. In the Critically Dry Flow Category, the median volume is 0.9 maf and the interquartile range is 192 kaf. Overall, the Representative Preferred Alternative has annual volumes on the low end of all alternatives.

Figure TA 3-29
Annual Flow Volume Below Imperial Dam[15]



Note: Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

[15] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-23** for the full range of the data.

Reach 7: NIB in the Limitrophe to SIB

This reach of the river (starting from the NIB) is split into two sub reaches. Approximately 1.1 miles downstream from the NIB is Morelos Diversion Dam where, under normal operations, the entirety of the remaining Colorado River is diverted by Mexico for water supply into the Reforma Canal.

Downstream of Morelos Diversion Dam, the reach continues to the SIB and the Colorado River Delta. Flows through this reach, referred to as the limitrophe, consist of water in excess of Mexico's scheduled delivery. Flows in excess could be due to Flood Control operations at Hoover Dam, seepage from Morelos Diversion Dam, irrigation return flows, groundwater inflow, and any water released for environmental purposes in the Colorado River Delta.

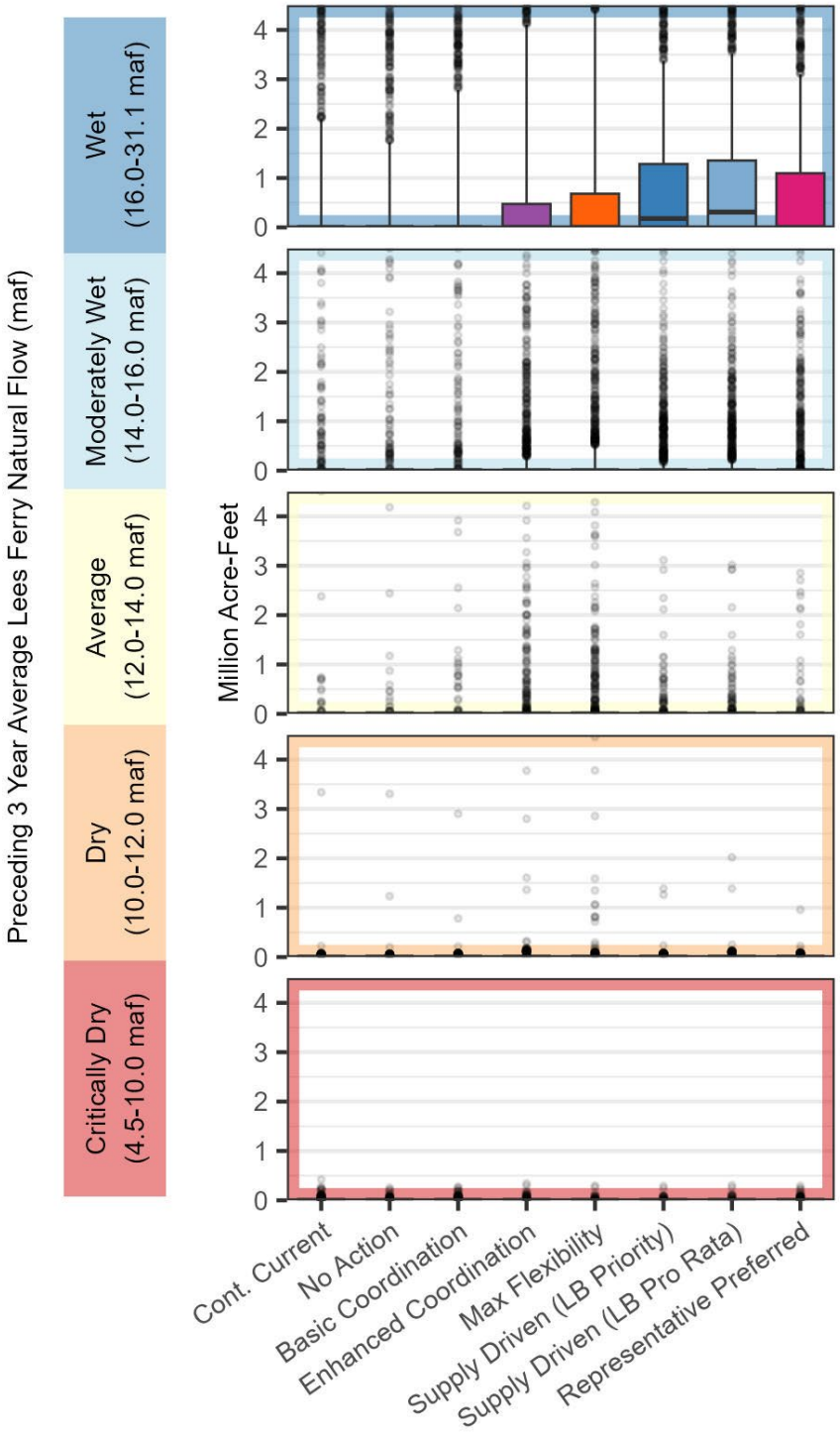
Figure TA 3-30 presents conditional boxplots of annual flow volume below Morelos Diversion Dam. The range of volumes is truncated to facilitate comparisons between alternatives, see **Table TA 3-24** at the end of this TA for the full statistical summary and full range of values.

In the Wet Flow Category, flows in the Colorado River below Morelos Diversion Dam occur in 50 percent of years for the Supply Driven Alternative (both LB Priority and Pro Rata approaches), greater than 25 percent of years for the Enhanced Coordination, Maximum Operational Flexibility and Representative Preferred Alternatives, and fewer than 25 percent of years for other alternatives and the CCS Comparative Baseline (i.e., the 75th percentile is 0).

As natural flow decreases, flows in the Colorado River below Morelos Diversion Dam become even less frequent. In the Average, Dry, and Critically Dry Flow Categories, flows occur in 10 percent or fewer years for all alternatives and the CCS Comparative Baseline (i.e. the 90th percentile is zero).

Although infrequent, there is the possibility of large volume flows in the limitrophe (e.g. greater than 1.0 maf in one calendar year) in all but the Critically Dry Flow Category. These are the result of exceptionally high flows that occur in some of the hydrologic futures considered in the modeling analysis.

Figure TA 3-30
Annual Flow Volume Below Morelos Diversion Dam[16]



[16] The plotting range has been truncated to facilitate comparison of the alternatives. Consult **Table TA 3-24** for the full range of the data.

TA 3.2.5 Issue 5: Groundwater

Issue 5 addresses how operational activities for the various alternatives would affect groundwater adjacent to reservoirs and within specific reaches along the Colorado River. This was evaluated by comparing the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Qualitative discussion of possible groundwater impacts based on relative changes to Colorado River flows for each reach, and relative changes to reservoir elevations where applicable.
- Hydraulic connectivity between groundwater and the reservoirs and river reaches of the Colorado River vary depending on a number of factors, including physical geotechnical characteristics, vegetative groundcover, whether irrigation is occurring nearby, and distance from the river.

Regional scale changes to groundwater are complex and hard to quantify without extensive data records and groundwater models. Current data on groundwater at a regional scale is limited in scope and historical duration.

There are no legal requirements to not deplete groundwater for nearby wells, although decreasing reservoir elevations may contribute to decreased groundwater elevations depending on hydraulic connectivity. Secondary impacts on groundwater are not considered in this analysis (e.g., if actions under the various alternatives would result in more groundwater pumping occurring in order to supplement decreased supply).

Reach 1: Lake Powell to Lake Mead

Fluctuations in elevations at Lake Powell may be reflected in groundwater elevations adjacent to the reservoir, depending on the hydraulic connectivity between the reservoir and nearby groundwater wells. Relating back to the Issue 1 analysis, the water surface elevations at Lake Powell vary by alternative with the Maximum Operational Flexibility Alternative and the Enhanced Coordination Alternative being the most robust at keeping elevations above 3,500 feet in 100 percent of months over the full modeling period (86 percent and 74 percent, respectively). Since these two alternatives are the most robust for reservoir elevations, groundwater elevations adjacent to Lake Powell are anticipated to be slightly higher under these alternatives compared to the others. The Representative Preferred Alternative is the third most robust (40 percent) followed by the CCS Comparative Baseline and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) (all 18 percent), and the Basic Coordination Alternative (13 percent). The No Action Alternative is the least robust at keeping Lake Powell elevations above 3,500 feet and is therefore anticipated to result in lower groundwater elevations adjacent to the reservoir.

Reach 1 of the Colorado River extends from downstream of Glen Canyon Dam, through the GCNP, to Lake Mead. The Grand Canyon restricts hydraulic connection to groundwater to sandbars. Due to physical geotechnical characteristics, changes to groundwater levels in this reach are not anticipated to be affected by the various alternatives.

Black Canyon, which is dammed by Hoover Dam, is made of bedrock that limits the connection to groundwater with a few small sandbars. As such, groundwater basins adjacent to Lake Mead are generally small in size and are bounded by zones of non-water bearing rock. Changes in water surface elevations at Lake Mead are not anticipated to be affected by the various alternatives.

Reach 2: Hoover Dam to Davis Dam

Reach 2 of the Colorado River extends from downstream of Hoover Dam to Lake Mohave (formed by Davis Dam) and runs through a bedrock canyon that limits the connection to groundwater. Due to physical geotechnical characteristics of the bedrock canyon, changes to groundwater levels in this reach are not anticipated to be affected by the various alternatives.

Groundwater elevations adjacent to Lake Mohave are not anticipated to be affected by the various alternatives because the release rule curve that Lake Mohave operates under is the same for all alternatives in this analysis. The rule curve keeps water surface elevations of Lake Mohave within a tight range and Reclamation will continue to operate releases from Davis Dam in this manner.

Reach 3: Davis Dam to Parker Dam

Reach 3 of the Colorado River extends from downstream of Davis Dam to Lake Havasu (formed by Parker Dam) and flows through two different groundwater basins. The upper portion of this reach is within the Mohave Valley groundwater basin, which is alluvial fill, and fluctuations in river flows through this section may affect groundwater in the alluvial basin.

Relating back to the Issue 4 analysis, the river flows in this reach are mostly comprised of releases from Davis Dam and tributary inflow from the Bill Williams River. Releases from Davis Dam vary by alternative, with the Basic Coordination Alternative having the highest flows in the reach under the Critically Dry Flow Category. Therefore, groundwater elevations through the Mohave Valley groundwater basin are anticipated to be higher under this alternative during dry conditions, compared to the others. Following this connection between river flows and adjacent groundwater elevations, the CCS Comparative Baseline is anticipated to have the second highest groundwater elevations in the Critically Dry Flow Category, closely followed by the No Action Alternative, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and the Representative Preferred Alternative. The Enhanced Coordination and the Maximum Operational Flexibility Alternatives are anticipated to result in lower groundwater elevations in dry conditions compared to the other alternatives.

The lower portion of this reach is within the Chemehuevi Valley and is dominated by Lake Havasu. Similar to Lake Mohave, the groundwater elevations adjacent to Lake Havasu are not anticipated to be affected by the various alternatives because of the strict release rule curve is the same for all alternatives within this analysis. The rule curve keeps water surface elevations of Lake Havasu within a tight range and Reclamation will continue to operate releases from Parker Dam in this manner.

Reach 4: Parker Dam to Cibola Gage

Reach 4 of the Colorado River extends from downstream of Parker Dam to the USGS gage station known as Cibola Gage. This reach flows through one large alluvial fill groundwater basin and fluctuations in river flows through this section may affect groundwater in this alluvial basin.

Relating back to the Issue 4 analysis, the river flows in this reach are mostly comprised of releases from Parker Dam which vary by alternative. In the Critically Dry Flow Category, the Basic Coordination Alternatives has the highest flows in the reach, therefore, groundwater elevations through this reach of the river are anticipated to be higher under this alternative compared to others. The Supply Driven Alternative (LB Priority approach) is anticipated to have the next highest groundwater elevations in the Critically Dry Flow Category, followed by the CCS Comparative Baseline, and the No Action, Representative Preferred, and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (LB Pro Rata approach) is anticipated to have the second lowest groundwater elevations in the Critically Dry Flow Category and the Enhanced Coordination Alternative is anticipated to have the lowest groundwater elevations.

Reach 5: Cibola Gage to Imperial Dam

Reach 5 of the Colorado River extends from the USGS gage station known as Cibola Gage down to Imperial Dam and runs through a narrow alluvial fill valley. Fluctuations in river flows through this section may affect groundwater.

Flows in this reach primarily consist of releases from Parker Dam and mirror trends in reach 4. As such, groundwater elevations in this reach of the river also mirror trends for relative groundwater elevations in Reach 4. In the Critically Dry Flow Category, The Basic Coordination Alternative is anticipated to have the highest groundwater elevations compared to the other alternatives. The CCS Comparative Baseline is anticipated to have the second highest groundwater elevations during in the Critically Dry Flow Category, closely followed by the Supply Driven (LB Priority approach), No Action, Representative Preferred, and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (LB Pro Rata approach) is anticipated to have the second lowest groundwater elevations in the Critically Dry Flow Category and the Enhanced Coordination Alternative is anticipated to have the lowest groundwater elevations.

Reach 6: Imperial Dam to NIB

Reach 6 of the Colorado River extends from downstream of Imperial Dam to the NIB and bypasses most of the river channel as it runs through a series of lined canals and sluiceways. Therefore, the proposed alternatives are not anticipated to affect groundwater basins adjacent to this reach.

Reach 7: NIB in the Limitrophe to SIB

Reach 7, referred to as the limitrophe, of the Colorado River extends from the NIB to the SIB and consists of the deep Colorado River Delta groundwater basin. Infrequent flows in this reach may occur due to releases at Morelos Diversion Dam under exceptionally wet hydrologic conditions.

The upstream portion of this reach is considered a gaining reach because high groundwater elevations from nearby irrigated fields results in flow to the surface. The proposed alternatives would not affect irrigation to nearby fields, therefore, there are no anticipated impacts on the groundwater in this section of the reach.

The downstream portion of this reach is considered a losing reach because groundwater is recharged from the river. Groundwater elevations in this section of the reach have historically declined and are likely to continue to decline under dry conditions.

TA 3.2.6 Summary Comparison of Alternatives

Issue 1: Reservoir Elevations

Issue 1 evaluates how operational activities under the CCS Comparative Baseline, No Action Alternative, and action alternatives would affect reservoir elevations at Lake Powell and Lake Mead. The analysis compares Lake Powell EOWY and WY minimum elevations, Lake Mead EOCY and CY minimum elevations, and the effects of Upper Basin and Lower Basin conservation assumptions on reservoir storage. Modeling shows fewer performance deviations under wetter flow categories, while differences among alternatives increase under dry and critically dry conditions because operations at lower elevations vary widely across alternatives.

Performance patterns vary by reservoir, alternative, flow category, and metric. At Lake Powell, differences among alternatives become more pronounced under drier hydrologic conditions, with some alternatives maintaining higher elevations and greater robustness above key thresholds, while others shift closer to or below those thresholds. At Lake Mead, the action alternatives perform better than the No Action Alternative for maintaining elevations above key thresholds, although results vary across alternatives and flow categories. Conservation activity increases median elevations for several action alternatives, but effects vary by reservoir, alternative, and flow category. Lake Mohave and Lake Havasu elevations are not affected because existing rule curves maintain target elevations within operational bounds.

Under the Representative Preferred Alternative, modeled results show reduced low-elevation outcomes compared to more vulnerable alternatives, but vulnerability remains under drier future hydrologic conditions. In the Dry and Critically Dry Flow Categories with conservation activity on, median EOWY elevations at Lake Powell are 3,554 feet and 3,523 feet, respectively, and median EOCY elevations at Lake Mead are 1,041 feet and 1,001 feet, respectively. Lake Powell robustness results for the key thresholds indicate that the Representative Preferred Alternative meets preferred minimum performance levels in about 40 to 50 percent of modeled futures over the full modeling period and about 52 to 58 percent of futures during 2027-2039. For Lake Mead, robustness results indicate that the alternative meets preferred minimum performance levels in about 57 to 63 percent of modeled futures over the full modeling period and about 62 to 72 percent of futures during 2027-2039. Vulnerability analyses indicate that, absent additional action, the Representative Preferred Alternative would be reasonably likely to be vulnerable in the next 10 years to elevations below key Lake Powell and Lake Mead thresholds under the 10-year average annual flow conditions identified in the modeling.

Issue 2: System Storage

Issue 2 evaluates how operational activities under the action alternatives would affect EOWY system storage compared to the No Action Alternative and CCS Comparative Baseline. The analysis considers combined storage at Lake Powell and Lake Mead, the CRSP reservoirs, and the seven-reservoir system. Across the alternatives, storage outcomes generally decline as hydrologic conditions become drier, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives often maintaining higher median storage than the No Action Alternative, Basic Coordination Alternative, and CCS Comparative Baseline. For Lake Powell and Lake Mead, alternatives with higher combined storage generally reduce the frequency of modeled years falling

below the lowest observed historical EOWY combined storage value. For CRSP reservoirs, differences are driven primarily by Lake Powell operations because storage at the CRSP UIU reservoirs varies minimally across alternatives. For the seven-reservoir system, alternatives capable of implementing larger Lower Basin shortages tend to result in greater seven-reservoir storage.

Overall, the results show differences among alternatives in their ability to maintain system storage under drier hydrologic conditions. The CCS Comparative Baseline and the No Action and Basic Coordination Alternatives generally show lower median storage than the Enhanced Coordination and Maximum Operational Flexibility Alternatives, and for Lake Powell and Lake Mead they also show a greater frequency of modeled years below lowest observed historical EOWY combined storage value. Under the Representative Preferred Alternative, modeled storage is lower under drier conditions: in the Dry Flow Category, median combined storage is 32 percent for Lake Powell and Lake Mead, 37 percent for CRSP reservoirs, and 37 percent for the seven-reservoir system. In the Critically Dry Flow Category, median storage declines to 21 percent for Lake Powell and Lake Mead, 27 percent for CRSP reservoirs, and 27 percent for the seven-reservoir system. For Lake Powell and Lake Mead specifically, more than 25 percent of modeled years in the Dry Flow Category and nearly 75 percent of modeled years in the Critically Dry Flow Category fall below the lowest observed historical EOWY combined storage value.

Issue 3: Reservoir Releases

Issue 3 evaluates how operational activities under the action alternatives would affect reservoir releases compared to the No Action Alternative and CCS Comparative Baseline, focusing on annual water year releases from Glen Canyon Dam, cumulative 10-year Glen Canyon Dam releases and Lee Ferry flows, and calendar year releases from Hoover, Davis, and Parker Dams. Across alternatives, modeled releases vary by hydrologic condition and by how operations respond to hydrologic and reservoir conditions, with drier conditions generally associated with lower median releases and, for many alternatives and locations, greater variability.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives generally show greater responsiveness to hydrologic conditions at Glen Canyon Dam and the Lee Ferry, while the No Action Alternative shows high variability under critically dry conditions due to infrastructure-constrained releases when Lake Powell falls below about 3,490 feet. At Hoover Dam, releases reflect modeled Lake Mead operations and conserved-water storage and delivery assumptions. At Davis and Parker Dams, releases also reflect inflows and target elevations defined by existing rule curves. Differences between the Supply Driven Alternative (LB Priority approach) and the Supply Driven Alternative (LB Pro Rata approach) at Lower Basin dams arise from how each shortage-distribution approach interacts with modeled conserved-water storage and delivery assumptions.

Under the Representative Preferred Alternative, Glen Canyon Dam releases are comparatively less variable under critically dry conditions, while modeled releases at Hoover, Davis, and Parker Dams are generally within the range of the other alternatives, with some variation by dam and hydrologic condition. Median annual Glen Canyon Dam releases decline from 7.20 maf in the Dry Flow Category to 6.0 maf in the Critically Dry Flow Category, reflecting reduced supply while remaining the least variable among alternatives under critically dry hydrology. At Lee Ferry, the Representative Preferred Alternative has median 10-year volumes of 76.4 maf under Dry conditions and 73.9 maf

under Critically Dry conditions. Under Dry conditions, more than half of modeled 10-year periods exceed 75.0 maf, but fewer than 25 percent exceed 82.5 maf. Under Critically Dry conditions, fewer than half of modeled 10-year periods exceed 75.0 maf, and slightly more than 10 percent exceed 82.5 maf. Downstream, the Representative Preferred Alternative releases at Hoover, Davis, and Parker Dams generally decrease as hydrologic conditions become drier. These releases are generally within the middle of the modeled alternatives or similar to most alternatives, with the main differences related to variability. Hoover releases are more variable under Critically Dry conditions, and Davis Dam releases show relatively higher variability under Dry conditions.

Issue 4: River Flows

Issue 4 evaluates how operational activities under the action alternatives would affect Colorado River flows compared to the No Action Alternative and CCS Comparative Baseline. The analysis considers annual flow volumes below Hoover Dam, below Davis Dam, below Parker Dam, at Imperial Dam, below Imperial Dam, and below Morelos Diversion Dam using three-year average natural flow model outputs across five flow categories. Across these reaches, modeled river flows generally decrease, or become less frequent below Morelos Diversion Dam, as hydrologic conditions become drier.

In the reaches from Glen Canyon Dam through Parker Dam, modeled comparisons generally focus on dam releases because those releases are the primary source of flow or the operational variable that differs among alternatives. Differences among alternatives are particularly apparent in drier hydrologic conditions and in reaches downstream of Parker Dam, where shortage distribution, conserved water assumptions, diversions, flows, and delivery requirements affect annual flow volumes and variability. Below Morelos Diversion Dam, flows are infrequent under all alternatives except during some wetter hydrologic conditions. In the Average, Dry, and Critically Dry Flow Categories, flows occur in 10 percent or fewer years for all alternatives and the CCS Comparative Baseline.

Under the Representative Preferred Alternative, annual flow volumes are generally in the middle of the range of alternatives and the CCS Comparative Baseline below Hoover Dam and Davis Dam. Below Parker Dam, annual volumes are similar to most alternatives, except for the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which are notably lower. Farther downstream, the Representative Preferred Alternative reflects the effects of diversions, return flows, delivery requirements, and increased shortages under drier conditions. At Imperial Dam, median annual flow under the Representative Preferred Alternative is 5.3 maf in the Dry Flow Category and 5.0 maf in the Critically Dry Flow Category. Below Imperial Dam, median annual flow is 0.9 maf in both the Dry and Critically Dry Flow Categories, which is on the low end of the alternatives. Below Morelos Diversion Dam, flows remain infrequent in the Average, Dry, and Critically Dry Flow Categories, occurring in 10 percent or fewer modeled years across all alternatives and the CCS Comparative Baseline.

Issue 5: Groundwater Elevations

Issue 5 evaluates how operational activities under the action alternatives could affect groundwater adjacent to reservoirs and along specific reaches of the Colorado River compared to the No Action Alternative and CCS Comparative Baseline. The analysis is qualitative because groundwater

responses are complex, available regional data are limited, and hydraulic connectivity varies by location. Groundwater effects are expected to be limited in many areas because some reaches are constrained by bedrock, lined canals, or reservoir operations that do not meaningfully vary across alternatives. Potential effects are most likely near Lake Powell, where reservoir elevations may influence adjacent groundwater, and in alluvial portions of the river where flow changes may affect groundwater elevations.

Overall, potential groundwater effects vary by reach and are most closely tied to Lake Powell elevations and relative river flows through connected groundwater basins. Alternatives that maintain higher Lake Powell elevations or higher flows in hydraulically connected alluvial reaches would generally be expected to support higher nearby groundwater elevations. Under the Representative Preferred Alternative, groundwater elevations near Lake Powell are anticipated to be lower than under the Maximum Operational Flexibility and Enhanced Coordination Alternatives but higher than under the CCS Comparative Baseline, No Action Alternative, Basic Coordination Alternative, and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). Across the river reaches, the Representative Preferred Alternative is expected to have little or no groundwater effect where hydraulic connectivity is limited or operations are similar across alternatives. Where flow-related groundwater effects are possible, it is generally not identified as producing either the highest or lowest anticipated groundwater elevations.

Statistical Summary Tables

Table TA 3-3
Minimum Water Year Elevation (Feet) at Lake Powell

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16.0-31.1	3,686	3,680	3,676	3,667	3,643	3,604	3,499
CCS Comparative Baseline	14.0-16.0	3,686	3,675	3,659	3,609	3,560	3,534	3,462
CCS Comparative Baseline	12.0-14.0	3,683	3,649	3,589	3,549	3,508	3,492	3,414
CCS Comparative Baseline	10.0-12.0	3,667	3,573	3,535	3,500	3,478	3,456	3,398
CCS Comparative Baseline	4.5-10.0	3,625	3,510	3,499	3,471	3,426	3,408	3,396
No Action	16.0-31.1	3,686	3,680	3,677	3,671	3,658	3,619	3,503
No Action	14.0-16.0	3,687	3,677	3,668	3,630	3,571	3,534	3,433
No Action	12.0-14.0	3,685	3,660	3,622	3,549	3,490	3,465	3,411
No Action	10.0-12.0	3,669	3,609	3,523	3,471	3,449	3,432	3,398
No Action	4.5-10.0	3,630	3,514	3,479	3,436	3,415	3,407	3,396
Basic Coordination	16.0-31.1	3,685	3,678	3,674	3,665	3,648	3,620	3,534
Basic Coordination	14.0-16.0	3,683	3,664	3,645	3,618	3,582	3,559	3,476
Basic Coordination	12.0-14.0	3,677	3,626	3,598	3,561	3,535	3,510	3,413
Basic Coordination	10.0-12.0	3,640	3,574	3,541	3,513	3,476	3,448	3,404
Basic Coordination	4.5-10.0	3,595	3,511	3,494	3,457	3,422	3,407	3,396
Enhanced Coordination	16.0-31.1	3,685	3,678	3,675	3,667	3,652	3,635	3,585
Enhanced Coordination	14.0-16.0	3,683	3,662	3,647	3,635	3,621	3,605	3,524
Enhanced Coordination	12.0-14.0	3,674	3,638	3,627	3,613	3,592	3,568	3,483
Enhanced Coordination	10.0-12.0	3,660	3,621	3,606	3,577	3,548	3,522	3,464
Enhanced Coordination	4.5-10.0	3,642	3,595	3,561	3,520	3,505	3,480	3,397
Max. Operational Flexibility	16.0-31.1	3,685	3,678	3,675	3,669	3,656	3,643	3,591
Max. Operational Flexibility	14.0-16.0	3,683	3,667	3,654	3,638	3,621	3,608	3,528
Max. Operational Flexibility	12.0-14.0	3,681	3,637	3,622	3,605	3,587	3,567	3,508
Max. Operational Flexibility	10.0-12.0	3,649	3,606	3,584	3,562	3,543	3,526	3,500
Max. Operational Flexibility	4.5-10.0	3,616	3,560	3,536	3,512	3,510	3,502	3,414
Supply Driven (LB Priority)	16.0-31.1	3,683	3,674	3,665	3,643	3,616	3,591	3,501
Supply Driven (LB Priority)	14.0-16.0	3,682	3,641	3,619	3,589	3,559	3,530	3,471
Supply Driven (LB Priority)	12.0-14.0	3,661	3,603	3,577	3,545	3,511	3,491	3,441
Supply Driven (LB Priority)	10.0-12.0	3,636	3,561	3,534	3,502	3,484	3,472	3,430
Supply Driven (LB Priority)	4.5-10.0	3,602	3,509	3,497	3,471	3,448	3,425	3,398
Supply Driven (LB Pro Rata)	16.0-31.1	3,683	3,674	3,665	3,643	3,616	3,591	3,501
Supply Driven (LB Pro Rata)	14.0-16.0	3,682	3,641	3,619	3,589	3,559	3,530	3,471
Supply Driven (LB Pro Rata)	12.0-14.0	3,661	3,603	3,577	3,545	3,511	3,491	3,441
Supply Driven (LB Pro Rata)	10.0-12.0	3,636	3,561	3,534	3,502	3,484	3,472	3,430
Supply Driven (LB Pro Rata)	4.5-10.0	3,602	3,509	3,497	3,471	3,448	3,425	3,398

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Representative Preferred	16.0-31.1	3,683	3,674	3,665	3,648	3,630	3,617	3,562
Representative Preferred	14.0-16.0	3,681	3,641	3,630	3,614	3,595	3,579	3,497
Representative Preferred	12.0-14.0	3,658	3,615	3,597	3,574	3,550	3,528	3,476
Representative Preferred	10.0-12.0	3,624	3,569	3,549	3,525	3,506	3,495	3,450
Representative Preferred	4.5-10.0	3,567	3,514	3,502	3,492	3,472	3,432	3,397

NOTE: Elevations colored blue are above the spill avoidance elevation of 3,680 feet, listed in **Table TA 3-2.**
Elevations colored red are below the minimum power pool elevation of 3,490 feet, listed in **Table TA 3-2**.

Table TA 3-4
EOWY Elevation (Feet) at Lake Powell

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16.0-31.1	3,696	3,692	3,690	3,679	3,657	3,621	3,499
CCS Comparative Baseline	14.0-16.0	3,697	3,690	3,676	3,635	3,580	3,549	3,462
CCS Comparative Baseline	12.0-14.0	3,695	3,670	3,624	3,574	3,527	3,500	3,414
CCS Comparative Baseline	10.0-12.0	3,694	3,616	3,565	3,517	3,498	3,468	3,404
CCS Comparative Baseline	4.5-10.0	3,689	3,560	3,525	3,499	3,457	3,424	3,398
No Action	16.0-31.1	3,696	3,693	3,690	3,684	3,670	3,637	3,503
No Action	14.0-16.0	3,696	3,691	3,684	3,654	3,595	3,551	3,433
No Action	12.0-14.0	3,697	3,681	3,643	3,585	3,517	3,478	3,411
No Action	10.0-12.0	3,695	3,629	3,571	3,498	3,473	3,447	3,407
No Action	4.5-10.0	3,688	3,571	3,517	3,478	3,443	3,421	3,400
Basic Coordination	16.0-31.1	3,695	3,692	3,689	3,678	3,658	3,632	3,534
Basic Coordination	14.0-16.0	3,696	3,688	3,668	3,638	3,600	3,570	3,476
Basic Coordination	12.0-14.0	3,696	3,658	3,625	3,588	3,551	3,520	3,413
Basic Coordination	10.0-12.0	3,695	3,613	3,579	3,538	3,497	3,466	3,404
Basic Coordination	4.5-10.0	3,676	3,574	3,535	3,487	3,452	3,422	3,398
Enhanced Coordination	16.0-31.1	3,696	3,692	3,690	3,679	3,661	3,642	3,585
Enhanced Coordination	14.0-16.0	3,696	3,689	3,671	3,648	3,629	3,613	3,528
Enhanced Coordination	12.0-14.0	3,696	3,669	3,651	3,629	3,604	3,575	3,483
Enhanced Coordination	10.0-12.0	3,694	3,650	3,627	3,597	3,561	3,533	3,464
Enhanced Coordination	4.5-10.0	3,690	3,622	3,596	3,557	3,524	3,496	3,399
Max. Operational Flexibility	16.0-31.1	3,697	3,692	3,691	3,682	3,664	3,649	3,591
Max. Operational Flexibility	14.0-16.0	3,696	3,691	3,679	3,653	3,632	3,614	3,528
Max. Operational Flexibility	12.0-14.0	3,696	3,671	3,650	3,624	3,598	3,575	3,508
Max. Operational Flexibility	10.0-12.0	3,695	3,641	3,618	3,584	3,558	3,537	3,500
Max. Operational Flexibility	4.5-10.0	3,692	3,615	3,582	3,546	3,520	3,508	3,431

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Supply Driven (LB Priority)	16.0-31.1	3,698	3,690	3,683	3,657	3,627	3,597	3,501
Supply Driven (LB Priority)	14.0-16.0	3,697	3,673	3,646	3,611	3,571	3,537	3,471
Supply Driven (LB Priority)	12.0-14.0	3,696	3,642	3,609	3,573	3,528	3,496	3,441
Supply Driven (LB Priority)	10.0-12.0	3,690	3,610	3,576	3,533	3,495	3,483	3,430
Supply Driven (LB Priority)	4.5-10.0	3,681	3,584	3,547	3,502	3,470	3,445	3,398
Supply Driven (LB Pro Rata)	16.0-31.1	3,698	3,690	3,683	3,657	3,627	3,597	3,501
Supply Driven (LB Pro Rata)	14.0-16.0	3,697	3,673	3,646	3,611	3,571	3,537	3,471
Supply Driven (LB Pro Rata)	12.0-14.0	3,696	3,642	3,609	3,573	3,528	3,496	3,441
Supply Driven (LB Pro Rata)	10.0-12.0	3,690	3,610	3,576	3,533	3,495	3,483	3,430
Supply Driven (LB Pro Rata)	4.5-10.0	3,681	3,584	3,547	3,502	3,470	3,445	3,398
Representative Preferred	16.0-31.1	3,696	3,690	3,683	3,661	3,639	3,620	3,553
Representative Preferred	14.0-16.0	3,696	3,678	3,656	3,629	3,606	3,585	3,507
Representative Preferred	12.0-14.0	3,699	3,653	3,627	3,595	3,563	3,539	3,476
Representative Preferred	10.0-12.0	3,689	3,616	3,588	3,554	3,529	3,508	3,454
Representative Preferred	4.5-10.0	3,680	3,592	3,555	3,523	3,498	3,468	3,398

NOTE: Elevations colored blue are above the spill avoidance elevation of 3,680 feet, listed in **Table TA 3-2**.
Elevations colored red are below the minimum power pool elevation of 3,490 feet, listed in **Table TA 3-2**.

Table TA 3-6
End of Calendar Year Elevations (Feet) at Lake Mead

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16.0-31.1	1,219	1,215	1,201	1,151	1,077	1,054	980
CCS Comparative Baseline	14.0-16.0	1,219	1,185	1,118	1,072	1,042	1,025	914
CCS Comparative Baseline	12.0-14.0	1,217	1,122	1,074	1,038	1,019	980	898
CCS Comparative Baseline	10.0-12.0	1,215	1,075	1,039	1,012	946	906	898
CCS Comparative Baseline	4.5-10.0	1,184	1,051	1,024	962	903	900	897
No Action	16.0-31.1	1,218	1,215	1,198	1,139	1,029	975	947
No Action	14.0-16.0	1,218	1,187	1,110	1,016	969	958	912
No Action	12.0-14.0	1,217	1,119	1,027	978	958	939	898
No Action	10.0-12.0	1,215	1,052	1,003	959	919	901	897
No Action	4.5-10.0	1,186	1,034	995	931	901	900	897
Basic Coordination	16.0-31.1	1,220	1,215	1,207	1,182	1,123	1,062	964
Basic Coordination	14.0-16.0	1,219	1,204	1,166	1,121	1,049	1,009	936
Basic Coordination	12.0-14.0	1,219	1,171	1,127	1,063	1,012	958	898
Basic Coordination	10.0-12.0	1,215	1,132	1,087	1,017	946	919	897
Basic Coordination	4.5-10.0	1,201	1,106	1,032	981	912	900	897

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Enhanced Coordination	16.0-31.1	1,220	1,217	1,215	1,207	1,173	1,131	1,046
Enhanced Coordination	14.0-16.0	1,220	1,217	1,205	1,150	1,115	1,086	983
Enhanced Coordination	12.0-14.0	1,220	1,199	1,143	1,109	1,073	1,046	923
Enhanced Coordination	10.0-12.0	1,220	1,135	1,102	1,061	1,025	986	898
Enhanced Coordination	4.5-10.0	1,196	1,098	1,046	1,008	961	904	897
Max. Operational Flexibility	16.0-31.1	1,220	1,218	1,216	1,211	1,188	1,126	1,040
Max. Operational Flexibility	14.0-16.0	1,229	1,217	1,212	1,176	1,109	1,063	985
Max. Operational Flexibility	12.0-14.0	1,229	1,212	1,183	1,126	1,056	1,024	929
Max. Operational Flexibility	10.0-12.0	1,220	1,188	1,144	1,054	1,013	991	901
Max. Operational Flexibility	4.5-10.0	1,220	1,153	1,061	1,013	979	928	897
Supply Driven (LB Priority)	16.0-31.1	1,220	1,219	1,218	1,215	1,197	1,143	1,007
Supply Driven (LB Priority)	14.0-16.0	1,220	1,218	1,211	1,188	1,135	1,079	977
Supply Driven (LB Priority)	12.0-14.0	1,220	1,203	1,184	1,150	1,070	1,027	920
Supply Driven (LB Priority)	10.0-12.0	1,220	1,176	1,153	1,067	1,004	948	899
Supply Driven (LB Priority)	4.5-10.0	1,194	1,144	1,076	1,011	933	905	897
Supply Driven (LB Pro Rata)	16.0-31.1	1,220	1,219	1,218	1,216	1,204	1,161	1,009
Supply Driven (LB Pro Rata)	14.0-16.0	1,220	1,218	1,213	1,195	1,154	1,106	984
Supply Driven (LB Pro Rata)	12.0-14.0	1,220	1,204	1,190	1,161	1,099	1,054	914
Supply Driven (LB Pro Rata)	10.0-12.0	1,219	1,181	1,163	1,096	1,031	971	898
Supply Driven (LB Pro Rata)	4.5-10.0	1,194	1,150	1,094	1,027	971	905	897
Representative Preferred	16.0-31.1	1,220	1,218	1,217	1,209	1,168	1,115	1,027
Representative Preferred	14.0-16.0	1,220	1,215	1,191	1,147	1,091	1,054	989
Representative Preferred	12.0-14.0	1,220	1,183	1,148	1,104	1,047	1,022	953
Representative Preferred	10.0-12.0	1,219	1,150	1,113	1,041	1,005	984	907
Representative Preferred	4.5-10.0	1,207	1,115	1,041	1,001	970	932	897

NOTE: Elevations colored blue are above the spillway elevation of 1,221 feet, listed in the previous table. Elevations colored red are below the minimum power pool elevation of 950 feet, listed in **Table TA 3-5**.

Table TA 3-7
Minimum Calendar Year Elevation (Feet) at Lake Mead

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	16.0-31.1	1,217	1,210	1,196	1,130	1,067	1,046	980
CCS Comparative Baseline	14.0-16.0	1,216	1,180	1,102	1,063	1,035	1,017	910
CCS Comparative Baseline	12.0-14.0	1,206	1,113	1,066	1,030	1,007	962	898
CCS Comparative Baseline	10.0-12.0	1,195	1,070	1,028	998	924	901	897
CCS Comparative Baseline	4.5-10.0	1,184	1,040	1,011	932	900	898	897
No Action	16.0-31.1	1,217	1,209	1,194	1,116	1,015	966	936
No Action	14.0-16.0	1,215	1,180	1,093	1,006	959	949	912
No Action	12.0-14.0	1,204	1,107	1,020	967	949	932	898
No Action	10.0-12.0	1,193	1,043	993	944	907	900	897
No Action	4.5-10.0	1,186	1,029	988	905	900	899	897
Basic Coordination	16.0-31.1	1,218	1,211	1,203	1,171	1,101	1,047	946
Basic Coordination	14.0-16.0	1,219	1,199	1,160	1,112	1,038	996	930
Basic Coordination	12.0-14.0	1,219	1,167	1,122	1,054	1,003	948	897
Basic Coordination	10.0-12.0	1,214	1,128	1,081	1,010	937	909	897
Basic Coordination	4.5-10.0	1,201	1,104	1,027	976	901	899	896
Enhanced Coordination	16.0-31.1	1,219	1,214	1,211	1,204	1,157	1,115	994
Enhanced Coordination	14.0-16.0	1,220	1,215	1,200	1,142	1,104	1,071	970
Enhanced Coordination	12.0-14.0	1,220	1,194	1,134	1,102	1,059	1,030	902
Enhanced Coordination	10.0-12.0	1,218	1,126	1,094	1,046	1,008	966	897
Enhanced Coordination	4.5-10.0	1,196	1,088	1,036	1,002	951	899	896
Max. Operational Flexibility	16.0-31.1	1,219	1,216	1,214	1,207	1,169	1,101	991
Max. Operational Flexibility	14.0-16.0	1,229	1,215	1,208	1,169	1,095	1,050	971
Max. Operational Flexibility	12.0-14.0	1,222	1,209	1,179	1,117	1,045	1,015	929
Max. Operational Flexibility	10.0-12.0	1,218	1,185	1,141	1,043	1,004	980	897
Max. Operational Flexibility	4.5-10.0	1,210	1,152	1,054	1,005	969	912	896
Supply Driven (LB Priority)	16.0-31.1	1,220	1,218	1,217	1,213	1,177	1,109	966
Supply Driven (LB Priority)	14.0-16.0	1,220	1,216	1,209	1,180	1,118	1,058	943
Supply Driven (LB Priority)	12.0-14.0	1,219	1,201	1,181	1,143	1,057	1,013	913
Supply Driven (LB Priority)	10.0-12.0	1,217	1,174	1,150	1,057	995	934	899
Supply Driven (LB Priority)	4.5-10.0	1,194	1,143	1,074	1,008	925	900	896
Supply Driven (LB Pro Rata)	16.0-31.1	1,220	1,218	1,217	1,214	1,186	1,130	961
Supply Driven (LB Pro Rata)	14.0-16.0	1,220	1,216	1,210	1,188	1,139	1,082	947
Supply Driven (LB Pro Rata)	12.0-14.0	1,219	1,202	1,187	1,155	1,085	1,038	914
Supply Driven (LB Pro Rata)	10.0-12.0	1,217	1,179	1,160	1,089	1,021	956	898
Supply Driven (LB Pro Rata)	4.5-10.0	1,194	1,149	1,093	1,024	963	900	897

Alternative	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Representative Preferred	16.0-31.1	1,220	1,218	1,216	1,199	1,145	1,091	1,001
Representative Preferred	14.0-16.0	1,220	1,213	1,185	1,139	1,077	1,042	975
Representative Preferred	12.0-14.0	1,219	1,180	1,144	1,097	1,036	1,012	945
Representative Preferred	10.0-12.0	1,212	1,146	1,108	1,030	995	974	898
Representative Preferred	4.5-10.0	1,207	1,111	1,033	990	957	914	896

NOTE: Elevations colored blue are above the spillway elevation of 1,221 feet, listed in **Table TA 3-5**. Elevations colored red are below the minimum power pool elevation of 950 feet, listed in **Table TA 3-5**.

Table TA 3-9
Impacts of Modeling Assumptions for Conservation Activity on End of Water Year Elevations (Feet) at Lake Powell

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	On	16.0-31.1	3,696	3,692	3,690	3,679	3,657	3,621	3,499
CCS Comparative Baseline	Off	16.0-31.1	3,696	3,692	3,690	3,679	3,659	3,623	3,499
CCS Comparative Baseline	On	14.0-16.0	3,697	3,690	3,676	3,635	3,580	3,549	3,462
CCS Comparative Baseline	Off	14.0-16.0	3,697	3,690	3,676	3,636	3,583	3,551	3,464
CCS Comparative Baseline	On	12.0-14.0	3,695	3,670	3,624	3,574	3,527	3,500	3,414
CCS Comparative Baseline	Off	12.0-14.0	3,695	3,670	3,626	3,576	3,531	3,500	3,414
CCS Comparative Baseline	On	10.0-12.0	3,694	3,616	3,565	3,517	3,498	3,468	3,404
CCS Comparative Baseline	Off	10.0-12.0	3,694	3,619	3,568	3,521	3,498	3,470	3,404
CCS Comparative Baseline	On	4.5-10.0	3,689	3,560	3,525	3,499	3,457	3,424	3,398
CCS Comparative Baseline	Off	4.5-10.0	3,689	3,561	3,527	3,499	3,458	3,424	3,398
No Action	On	16.0-31.1	3,696	3,693	3,690	3,684	3,670	3,637	3,503
No Action	Off	16.0-31.1	3,696	3,693	3,690	3,684	3,671	3,637	3,503
No Action	On	14.0-16.0	3,696	3,691	3,684	3,654	3,595	3,551	3,433
No Action	Off	14.0-16.0	3,696	3,691	3,684	3,654	3,595	3,551	3,433
No Action	On	12.0-14.0	3,697	3,681	3,643	3,585	3,517	3,478	3,411
No Action	Off	12.0-14.0	3,697	3,681	3,643	3,585	3,517	3,478	3,411

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
No Action	On	10.0-12.0	3,695	3,629	3,571	3,498	3,473	3,447	3,407
No Action	Off	10.0-12.0	3,695	3,629	3,571	3,498	3,473	3,447	3,407
No Action	On	4.5-10.0	3,688	3,571	3,517	3,478	3,443	3,421	3,400
No Action	Off	4.5-10.0	3,688	3,571	3,517	3,478	3,443	3,421	3,400
Basic Coordination	On	16.0-31.1	3,695	3,692	3,689	3,678	3,658	3,632	3,534
Basic Coordination	Off	16.0-31.1	3,695	3,692	3,689	3,678	3,659	3,632	3,534
Basic Coordination	On	14.0-16.0	3,696	3,688	3,668	3,638	3,600	3,570	3,476
Basic Coordination	Off	14.0-16.0	3,696	3,688	3,669	3,638	3,600	3,570	3,476
Basic Coordination	On	12.0-14.0	3,696	3,658	3,625	3,588	3,551	3,520	3,413
Basic Coordination	Off	12.0-14.0	3,696	3,658	3,625	3,588	3,551	3,520	3,413
Basic Coordination	On	10.0-12.0	3,695	3,613	3,579	3,538	3,497	3,466	3,404
Basic Coordination	Off	10.0-12.0	3,695	3,613	3,579	3,538	3,497	3,466	3,404
Basic Coordination	On	4.5-10.0	3,676	3,574	3,535	3,487	3,452	3,422	3,398
Basic Coordination	Off	4.5-10.0	3,676	3,574	3,535	3,487	3,452	3,422	3,398
Enhanced Coordination	On	16.0-31.1	3,696	3,692	3,690	3,679	3,661	3,642	3,585
Enhanced Coordination	Off	16.0-31.1	3,695	3,692	3,689	3,676	3,657	3,638	3,586
Enhanced Coordination	On	14.0-16.0	3,696	3,689	3,671	3,648	3,629	3,613	3,528
Enhanced Coordination	Off	14.0-16.0	3,695	3,686	3,666	3,643	3,626	3,610	3,534
Enhanced Coordination	On	12.0-14.0	3,696	3,669	3,651	3,629	3,604	3,575	3,483
Enhanced Coordination	Off	12.0-14.0	3,695	3,664	3,645	3,623	3,600	3,575	3,484
Enhanced Coordination	On	10.0-12.0	3,694	3,650	3,627	3,597	3,561	3,533	3,464
Enhanced Coordination	Off	10.0-12.0	3,692	3,644	3,621	3,593	3,561	3,531	3,464
Enhanced Coordination	On	4.5-10.0	3,690	3,622	3,596	3,557	3,524	3,496	3,399
Enhanced Coordination	Off	4.5-10.0	3,687	3,617	3,592	3,556	3,524	3,495	3,399

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Max. Operational Flexibility	On	16.0-31.1	3,697	3,692	3,691	3,682	3,664	3,649	3,591
Max. Operational Flexibility	Off	16.0-31.1	3,696	3,692	3,690	3,680	3,661	3,647	3,596
Max. Operational Flexibility	On	14.0-16.0	3,696	3,691	3,679	3,653	3,632	3,614	3,528
Max. Operational Flexibility	Off	14.0-16.0	3,696	3,689	3,675	3,650	3,630	3,612	3,540
Max. Operational Flexibility	On	12.0-14.0	3,696	3,671	3,650	3,624	3,598	3,575	3,508
Max. Operational Flexibility	Off	12.0-14.0	3,695	3,668	3,646	3,621	3,595	3,575	3,508
Max. Operational Flexibility	On	10.0-12.0	3,695	3,641	3,618	3,584	3,558	3,537	3,500
Max. Operational Flexibility	Off	10.0-12.0	3,695	3,637	3,615	3,581	3,556	3,536	3,502
Max. Operational Flexibility	On	4.5-10.0	3,692	3,615	3,582	3,546	3,520	3,508	3,431
Max. Operational Flexibility	Off	4.5-10.0	3,689	3,611	3,578	3,543	3,519	3,507	3,431
Supply Driven (LB Priority)	On	16.0-31.1	3,698	3,690	3,683	3,657	3,627	3,597	3,501
Supply Driven (LB Priority)	Off	16.0-31.1	3,698	3,690	3,679	3,651	3,619	3,588	3,492
Supply Driven (LB Priority)	On	14.0-16.0	3,697	3,673	3,646	3,611	3,571	3,537	3,471
Supply Driven (LB Priority)	Off	14.0-16.0	3,696	3,666	3,638	3,602	3,560	3,524	3,471
Supply Driven (LB Priority)	On	12.0-14.0	3,696	3,642	3,609	3,573	3,528	3,496	3,441
Supply Driven (LB Priority)	Off	12.0-14.0	3,695	3,635	3,601	3,565	3,520	3,493	3,439
Supply Driven (LB Priority)	On	10.0-12.0	3,690	3,610	3,576	3,533	3,495	3,483	3,430
Supply Driven (LB Priority)	Off	10.0-12.0	3,688	3,604	3,571	3,528	3,493	3,481	3,431
Supply Driven (LB Priority)	On	4.5-10.0	3,681	3,584	3,547	3,502	3,470	3,445	3,398
Supply Driven (LB Priority)	Off	4.5-10.0	3,679	3,580	3,543	3,498	3,469	3,445	3,398
Supply Driven (LB Pro Rata)	On	16.0-31.1	3,698	3,690	3,683	3,657	3,627	3,597	3,501
Supply Driven (LB Pro Rata)	Off	16.0-31.1	3,698	3,690	3,679	3,651	3,619	3,588	3,492
Supply Driven (LB Pro Rata)	On	14.0-16.0	3,697	3,673	3,646	3,611	3,571	3,537	3,471
Supply Driven (LB Pro Rata)	Off	14.0-16.0	3,696	3,666	3,638	3,602	3,560	3,524	3,471

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Supply Driven (LB Pro Rata)	On	12.0-14.0	3,696	3,642	3,609	3,573	3,528	3,496	3,441
Supply Driven (LB Pro Rata)	Off	12.0-14.0	3,695	3,635	3,601	3,565	3,520	3,493	3,439
Supply Driven (LB Pro Rata)	On	10.0-12.0	3,690	3,610	3,576	3,533	3,495	3,483	3,430
Supply Driven (LB Pro Rata)	Off	10.0-12.0	3,688	3,604	3,571	3,528	3,493	3,481	3,431
Supply Driven (LB Pro Rata)	On	4.5-10.0	3,681	3,584	3,547	3,502	3,470	3,445	3,398
Supply Driven (LB Pro Rata)	Off	4.5-10.0	3,679	3,580	3,543	3,498	3,469	3,445	3,398
Representative Preferred	On	16.0-31.1	3,696	3,690	3,683	3,661	3,639	3,620	3,553
Representative Preferred	Off	16.0-31.1	3,696	3,689	3,681	3,658	3,637	3,619	3,546
Representative Preferred	On	14.0-16.0	3,696	3,678	3,656	3,629	3,606	3,585	3,507
Representative Preferred	Off	14.0-16.0	3,696	3,676	3,654	3,627	3,603	3,581	3,505
Representative Preferred	On	12.0-14.0	3,699	3,653	3,627	3,595	3,563	3,539	3,474
Representative Preferred	Off	12.0-14.0	3,697	3,650	3,624	3,591	3,561	3,537	3,454
Representative Preferred	On	10.0-12.0	3,689	3,616	3,588	3,554	3,529	3,508	3,454
Representative Preferred	Off	10.0-12.0	3,688	3,613	3,585	3,552	3,528	3,507	3,454
Representative Preferred	On	4.5-10.0	3,680	3,592	3,555	3,523	3,498	3,468	3,398
Representative Preferred	Off	4.5-10.0	3,679	3,590	3,553	3,522	3,498	3,468	3,398

NOTE: Elevations colored blue are above the spill avoidance elevation of 3,680 feet, listed in **Table TA 3-2**.
Elevations colored red are below the minimum power pool elevation of 3,490 feet, listed in **Table TA 3-2**.

Table TA 3-10
Impacts of Modeling Assumptions for Conservation Activity on End of Calendar Year Elevations (Feet) at Lake Mead

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	On	16.0-31.1	1,219	1,215	1,201	1,151	1,077	1,054	980
CCS Comparative Baseline	Off	16.0-31.1	1,219	1,215	1,199	1,155	1,080	1,057	981
CCS Comparative Baseline	On	14.0-16.0	1,219	1,185	1,118	1,072	1,042	1,025	914
CCS Comparative Baseline	Off	14.0-16.0	1,218	1,183	1,120	1,074	1,046	1,028	915
CCS Comparative Baseline	On	12.0-14.0	1,217	1,122	1,074	1,038	1,019	980	898
CCS Comparative Baseline	Off	12.0-14.0	1,217	1,121	1,075	1,041	1,022	984	898
CCS Comparative Baseline	On	10.0-12.0	1,215	1,075	1,039	1,012	946	906	898
CCS Comparative Baseline	Off	10.0-12.0	1,215	1,077	1,042	1,019	952	907	898

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
CCS Comparative Baseline	On	4.5-10.0	1,184	1,051	1,024	962	903	900	897
CCS Comparative Baseline	Off	4.5-10.0	1,177	1,053	1,027	970	903	900	897
No Action	On	16.0-31.1	1,218	1,215	1,198	1,139	1,029	975	947
No Action	Off	16.0-31.1	1,219	1,215	1,199	1,147	1,038	976	945
No Action	On	14.0-16.0	1,218	1,187	1,110	1,016	969	958	912
No Action	Off	14.0-16.0	1,218	1,188	1,115	1,025	969	958	912
No Action	On	12.0-14.0	1,217	1,119	1,027	978	958	939	898
No Action	Off	12.0-14.0	1,217	1,124	1,036	981	959	939	897
No Action	On	10.0-12.0	1,215	1,052	1,003	959	919	901	897
No Action	Off	10.0-12.0	1,215	1,058	1,011	960	918	901	897
No Action	On	4.5-10.0	1,186	1,034	995	931	901	900	897
No Action	Off	4.5-10.0	1,185	1,040	1,003	933	901	900	897
Basic Coordination	On	16.0-31.1	1,220	1,215	1,207	1,182	1,123	1,062	964
Basic Coordination	Off	16.0-31.1	1,220	1,215	1,207	1,186	1,133	1,072	962
Basic Coordination	On	14.0-16.0	1,219	1,204	1,166	1,121	1,049	1,009	936
Basic Coordination	Off	14.0-16.0	1,219	1,204	1,171	1,125	1,062	1,012	935
Basic Coordination	On	12.0-14.0	1,219	1,171	1,127	1,063	1,012	958	898
Basic Coordination	Off	12.0-14.0	1,219	1,174	1,131	1,077	1,019	959	899
Basic Coordination	On	10.0-12.0	1,215	1,132	1,087	1,017	946	919	897
Basic Coordination	Off	10.0-12.0	1,215	1,135	1,095	1,027	946	918	897
Basic Coordination	On	4.5-10.0	1,201	1,106	1,032	981	912	900	897
Basic Coordination	Off	4.5-10.0	1,201	1,110	1,040	991	912	900	896
Enhanced Coordination	On	16.0-31.1	1,220	1,217	1,215	1,207	1,173	1,131	1,046
Enhanced Coordination	Off	16.0-31.1	1,220	1,216	1,213	1,198	1,149	1,119	1,033
Enhanced Coordination	On	14.0-16.0	1,220	1,217	1,205	1,150	1,115	1,086	983
Enhanced Coordination	Off	14.0-16.0	1,220	1,213	1,177	1,132	1,109	1,085	999
Enhanced Coordination	On	12.0-14.0	1,220	1,199	1,143	1,109	1,073	1,046	923
Enhanced Coordination	Off	12.0-14.0	1,220	1,171	1,125	1,102	1,073	1,045	912
Enhanced Coordination	On	10.0-12.0	1,220	1,135	1,102	1,061	1,025	986	898
Enhanced Coordination	Off	10.0-12.0	1,217	1,119	1,092	1,060	1,025	978	896
Enhanced Coordination	On	4.5-10.0	1,196	1,098	1,046	1,008	961	904	897
Enhanced Coordination	Off	4.5-10.0	1,179	1,085	1,045	1,013	955	902	897
Max. Operational Flexibility	On	16.0-31.1	1,220	1,218	1,216	1,211	1,188	1,126	1,040
Max. Operational Flexibility	Off	16.0-31.1	1,220	1,217	1,215	1,198	1,144	1,098	1,003
Max. Operational Flexibility	On	14.0-16.0	1,229	1,217	1,212	1,176	1,109	1,063	985
Max. Operational Flexibility	Off	14.0-16.0	1,220	1,212	1,179	1,124	1,083	1,050	955
Max. Operational Flexibility	On	12.0-14.0	1,229	1,212	1,183	1,126	1,056	1,024	929
Max. Operational Flexibility	Off	12.0-14.0	1,219	1,180	1,129	1,091	1,048	1,018	905
Max. Operational Flexibility	On	10.0-12.0	1,220	1,188	1,144	1,054	1,013	991	901
Max. Operational Flexibility	Off	10.0-12.0	1,217	1,136	1,099	1,049	1,008	969	898
Max. Operational Flexibility	On	4.5-10.0	1,220	1,153	1,061	1,013	979	928	897
Max. Operational Flexibility	Off	4.5-10.0	1,197	1,106	1,054	1,013	966	915	897

Alternative	Activity	Flow Category	Max (feet)	90% (feet)	75% (feet)	50% (feet)	25% (feet)	10% (feet)	Min (feet)
Supply Driven (LB Priority)	On	16.0-31.1	1,220	1,219	1,218	1,215	1,197	1,143	1,007
Supply Driven (LB Priority)	Off	16.0-31.1	1,220	1,218	1,216	1,198	1,166	1,128	1,010
Supply Driven (LB Priority)	On	14.0-16.0	1,220	1,218	1,211	1,188	1,135	1,079	977
Supply Driven (LB Priority)	Off	14.0-16.0	1,220	1,213	1,185	1,151	1,114	1,071	976
Supply Driven (LB Priority)	On	12.0-14.0	1,220	1,203	1,184	1,150	1,070	1,027	920
Supply Driven (LB Priority)	Off	12.0-14.0	1,219	1,177	1,144	1,115	1,056	1,019	919
Supply Driven (LB Priority)	On	10.0-12.0	1,220	1,176	1,153	1,067	1,004	948	899
Supply Driven (LB Priority)	Off	10.0-12.0	1,215	1,133	1,110	1,044	992	945	899
Supply Driven (LB Priority)	On	4.5-10.0	1,194	1,144	1,076	1,011	933	905	897
Supply Driven (LB Priority)	Off	4.5-10.0	1,186	1,098	1,039	995	926	904	897
Supply Driven (LB Pro Rata)	On	16.0-31.1	1,220	1,219	1,218	1,216	1,204	1,161	1,009
Supply Driven (LB Pro Rata)	Off	16.0-31.1	1,220	1,218	1,216	1,198	1,166	1,127	1,006
Supply Driven (LB Pro Rata)	On	14.0-16.0	1,220	1,218	1,213	1,195	1,154	1,106	984
Supply Driven (LB Pro Rata)	Off	14.0-16.0	1,220	1,213	1,185	1,151	1,114	1,071	980
Supply Driven (LB Pro Rata)	On	12.0-14.0	1,220	1,204	1,190	1,161	1,099	1,054	914
Supply Driven (LB Pro Rata)	Off	12.0-14.0	1,219	1,177	1,143	1,115	1,056	1,018	913
Supply Driven (LB Pro Rata)	On	10.0-12.0	1,219	1,181	1,163	1,096	1,031	971	898
Supply Driven (LB Pro Rata)	Off	10.0-12.0	1,215	1,133	1,110	1,043	991	941	897
Supply Driven (LB Pro Rata)	On	4.5-10.0	1,194	1,150	1,094	1,027	971	905	897
Supply Driven (LB Pro Rata)	Off	4.5-10.0	1,186	1,097	1,038	995	922	902	897
Representative Preferred	On	16.0-31.1	1,220	1,218	1,217	1,209	1,168	1,115	1,027
Representative Preferred	Off	16.0-31.1	1,220	1,218	1,216	1,197	1,153	1,101	1,023
Representative Preferred	On	14.0-16.0	1,220	1,215	1,191	1,147	1,091	1,054	989
Representative Preferred	Off	14.0-16.0	1,220	1,208	1,175	1,131	1,075	1,044	995
Representative Preferred	On	12.0-14.0	1,220	1,183	1,148	1,104	1,047	1,022	953
Representative Preferred	Off	12.0-14.0	1,219	1,167	1,130	1,086	1,037	1,018	947
Representative Preferred	On	10.0-12.0	1,219	1,150	1,113	1,041	1,005	984	907
Representative Preferred	Off	10.0-12.0	1,215	1,132	1,096	1,029	1,002	981	906
Representative Preferred	On	4.5-10.0	1,207	1,115	1,041	1,001	970	932	897
Representative Preferred	Off	4.5-10.0	1,197	1,099	1,027	995	965	924	897

NOTE: Elevations colored blue are above the spillway elevation of 1,221 feet, listed in **Table TA 3-5**.
Elevations colored red are below the minimum power pool elevation of 950 feet, listed in **Table TA 3-5**.

Table TA 3-11
EOWY Powell and Mead Combined Storage (% Full)

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
CCS Comparative Baseline	16.0-31.1	98.2	96.4	90.7	74.3	54.9	42.3	15.8
CCS Comparative Baseline	14.0-16.0	98.1	84.6	66.9	47.4	33.6	26.5	8.2
CCS Comparative Baseline	12.0-14.0	97.7	65.0	44.9	31.6	22.9	15.4	2.4
CCS Comparative Baseline	10.0-12.0	95.7	43.5	30.4	20.9	11.9	7.1	1.6
CCS Comparative Baseline	4.5-10.0	78.1	31.8	22.6	13.3	5.7	3.0	1.5
No Action	16.0-31.1	98.3	96.1	89.9	72.5	51.3	38.4	13.0
No Action	14.0-16.0	98.1	85.2	66.2	43.7	28.4	19.9	4.9
No Action	12.0-14.0	97.4	64.7	42.4	26.6	15.9	9.9	2.2
No Action	10.0-12.0	95.5	42.4	25.9	14.5	7.8	4.8	1.9
No Action	4.5-10.0	78.0	29.4	19.4	9.0	4.4	2.8	1.6
Basic Coordination	16.0-31.1	98.5	96.5	92.4	80.5	63.7	48.4	17.5
Basic Coordination	14.0-16.0	98.4	88.1	74.2	56.1	38.5	28.8	9.9
Basic Coordination	12.0-14.0	97.5	70.2	53.1	38.4	25.7	17.6	2.5
Basic Coordination	10.0-12.0	95.8	51.7	37.6	24.9	13.4	7.4	1.9
Basic Coordination	4.5-10.0	77.5	38.4	26.1	15.5	5.9	3.1	1.4
Enhanced Coordination	16.0-31.1	98.5	97.0	95.2	87.2	77.0	63.9	40.3
Enhanced Coordination	14.0-16.0	98.6	92.2	82.7	68.9	56.1	46.9	18.5
Enhanced Coordination	12.0-14.0	98.1	79.6	65.8	54.5	42.9	33.7	10.2
Enhanced Coordination	10.0-12.0	96.0	63.6	51.7	38.8	28.3	19.9	5.6
Enhanced Coordination	4.5-10.0	85.5	49.5	36.3	25.1	16.9	10.2	1.6
Max. Operational Flexibility	16.0-31.1	98.5	97.2	95.7	89.5	81.1	64.7	38.3
Max. Operational Flexibility	14.0-16.0	99.8	94.8	86.6	73.6	56.2	45.2	20.7
Max. Operational Flexibility	12.0-14.0	98.4	84.0	71.1	55.8	41.1	32.1	11.9
Max. Operational Flexibility	10.0-12.0	98.5	68.8	55.0	38.0	26.9	21.2	9.1
Max. Operational Flexibility	4.5-10.0	90.3	54.2	37.3	24.8	18.0	12.3	3.2
Supply Driven (LB Priority)	16.0-31.1	98.5	96.7	92.8	84.3	73.6	59.0	31.0
Supply Driven (LB Priority)	14.0-16.0	98.3	88.0	78.5	65.8	50.3	38.5	14.5
Supply Driven (LB Priority)	12.0-14.0	98.1	74.3	61.9	49.3	35.2	24.7	5.7
Supply Driven (LB Priority)	10.0-12.0	95.6	59.2	47.9	33.3	20.3	12.6	4.0
Supply Driven (LB Priority)	4.5-10.0	76.4	45.3	32.8	20.6	10.6	5.8	1.5
Supply Driven (LB Pro Rata)	16.0-31.1	99.4	96.7	93.1	85.0	74.9	62.7	35.3
Supply Driven (LB Pro Rata)	14.0-16.0	98.7	88.4	79.4	67.7	53.8	42.9	14.8
Supply Driven (LB Pro Rata)	12.0-14.0	98.1	75.3	63.6	51.9	39.6	29.5	5.7
Supply Driven (LB Pro Rata)	10.0-12.0	96.6	60.7	50.0	37.0	24.4	14.9	4.0
Supply Driven (LB Pro Rata)	4.5-10.0	78.7	46.8	35.2	23.3	13.8	6.4	1.4

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
Representative Preferred	16.0-31.1	98.5	96.5	91.6	82.4	70.5	56.7	27.3
Representative Preferred	14.0-16.0	98.6	86	75.8	62.4	47.6	37.9	18.3
Representative Preferred	12.0-14.0	97.8	71.5	57.9	45.9	33.6	26.2	10.1
Representative Preferred	10.0-12.0	94.8	54.8	43.5	31.5	22.3	17.4	6.9
Representative Preferred	4.5-10.0	74.5	41.5	30.7	20.8	14.1	8.3	1.4

Table TA 3-12
EOWY CRSP Combined Storage (% Full)

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
CCS Comparative Baseline	16.0-31.1	94.9	92.4	91.2	85.3	74.9	59.2	21.8
CCS Comparative Baseline	14.0-16.0	94.7	91.4	84.2	65.8	45.6	33.2	11.4
CCS Comparative Baseline	12.0-14.0	94.7	81.1	61.8	44.2	28.4	20.1	6.0
CCS Comparative Baseline	10.0-12.0	93.1	58.4	41.3	26.7	19.2	14.7	4.9
CCS Comparative Baseline	4.5-10.5	91.6	40.9	30.5	21.0	13.2	8.6	4.1
No Action	16.0-31.1	95.1	92.8	91.8	88.2	81.0	66.3	31.6
No Action	14.0-16.0	95.2	92.2	88.3	73.9	52.5	40.8	18.6
No Action	12.0-14.0	95.5	86.7	69.2	49.6	33.9	26.9	12.7
No Action	10.0-12.0	94.8	63.9	45.9	31.0	25.8	21.6	10.7
No Action	4.5-10.5	91.3	45.6	33.7	25.8	20.4	16.8	5.0
Basic Coordination	16.0-31.1	95.4	92.4	91.1	84.9	74.9	63.1	31.0
Basic Coordination	14.0-16.0	94.6	90.8	80.1	67.0	52.6	42.5	13.5
Basic Coordination	12.0-14.0	94.6	75.4	62.2	48.3	35.8	25.7	5.2
Basic Coordination	10.0-12.0	93.1	57.5	45.0	31.7	20.5	14.3	4.8
Basic Coordination	4.5-10.5	86.5	44.2	32.9	21.1	12.6	8.6	4.1
Enhanced Coordination	16.0-31.1	94.9	92.7	91.7	85.4	76.5	68.5	48.5
Enhanced Coordination	14.0-16.0	95.1	91.1	82.0	71.7	63.4	57.4	33.2
Enhanced Coordination	12.0-14.0	95.5	81.1	73.0	63.5	54.1	46.2	22.2
Enhanced Coordination	10.0-12.0	93.8	72.7	63.1	52.3	42.4	35.4	18.4
Enhanced Coordination	4.5-10.5	92.1	61.2	52.1	40.6	32.8	27.1	7.2
Max. Operational Flexibility	16.0-31.1	95.3	92.8	91.8	87.0	78.0	70.8	50.4
Max. Operational Flexibility	14.0-16.0	95.2	91.9	85.9	73.9	64.7	57.8	32.8
Max. Operational Flexibility	12.0-14.0	94.8	82.3	72.6	61.8	52.5	46.0	27.6
Max. Operational Flexibility	10.0-12.0	93.9	69.1	60.2	48.6	41.5	35.9	21.3
Max. Operational Flexibility	4.5-10.5	93.2	59.2	48.0	38.5	32.1	28.5	11.1

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
Supply Driven (LB Priority)	16.0-31.1	95.2	91.9	87.7	74.7	63.0	51.3	26.1
Supply Driven (LB Priority)	14.0-16.0	94.1	82.7	70.5	57.1	43.6	35.2	17.0
Supply Driven (LB Priority)	12.0-14.0	94.3	69.2	56.4	44.7	32.9	26.0	9.9
Supply Driven (LB Priority)	10.0-12.0	92.5	56.8	45.4	33.6	24.7	19.4	7.9
Supply Driven (LB Priority)	4.5-10.5	87.5	47.0	36.7	25.8	18.0	12.7	4.3
Supply Driven (LB Pro Rata)	16.0-31.1	95.2	91.9	87.7	74.7	63.0	51.3	26.1
Supply Driven (LB Pro Rata)	14.0-16.0	94.1	82.7	70.5	57.1	43.6	35.2	17.0
Supply Driven (LB Pro Rata)	12.0-14.0	94.3	69.2	56.4	44.7	32.9	26.0	9.9
Supply Driven (LB Pro Rata)	10.0-12.0	92.5	56.8	45.4	33.6	24.7	19.4	7.9
Supply Driven (LB Pro Rata)	4.5-10.5	87.5	47.0	36.7	25.8	18.0	12.7	4.3
Representative Preferred	16.0-31.1	95.0	91.8	87.6	76.9	66.9	59.5	39.3
Representative Preferred	14.0-16.0	94.3	85.4	75.2	63.8	54.3	47.1	18.7
Representative Preferred	12.0-14.0	94.6	73.7	62.8	50.7	40.5	32.3	13.9
Representative Preferred	10.0-12.0	92.9	58.5	48.9	37.2	28.3	21.8	11.0
Representative Preferred	4.5-10.5	88.2	48.7	37.7	27.4	19.2	14.2	4.3

Table TA 3-13
EOWY Seven-Reservoir Combined Storage (% Full)

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
CCS Comparative Baseline	16.0-31.1	96.8	94.9	89.7	75.8	58.8	47.3	22.4
CCS Comparative Baseline	14.0-16.0	96.6	84.6	69.5	52.5	39.4	31.4	12.9
CCS Comparative Baseline	12.0-14.0	96.2	67.6	50.2	38.0	27.8	20.0	7.4
CCS Comparative Baseline	10.0-12.0	94.8	49.5	36.7	26.1	16.7	12.4	6.4
CCS Comparative Baseline	4.5-10.0	79.5	38.1	29.3	19.2	11.2	8.5	6.3
No Action	16.0-31.1	96.8	94.8	89.2	74.5	56.1	45.0	23.4
No Action	14.0-16.0	96.6	85.0	68.8	49.7	36.4	29.2	14.7
No Action	12.0-14.0	96.0	67.6	48.6	34.9	25.7	20.3	10.4
No Action	10.0-12.0	94.6	48.3	34.4	24.5	18.4	15.5	9.5
No Action	4.5-10.0	79.5	36.9	28.5	19.5	14.8	12.7	6.7
Basic Coordination	16.0-31.1	96.9	95.1	91.2	80.7	66.7	52.7	23.9
Basic Coordination	14.0-16.0	96.7	87.6	75.7	60.2	44.6	34.9	14.4
Basic Coordination	12.0-14.0	96.0	72.4	57.3	44.2	31.9	22.4	6.8
Basic Coordination	10.0-12.0	94.8	55.9	42.8	30.4	18.4	12.6	6.6
Basic Coordination	4.5-10.0	79.0	43.2	32.1	21.4	11.5	8.6	6.0
Enhanced Coordination	16.0-31.1	96.9	95.5	93.7	86.7	77.9	66.8	46.1
Enhanced Coordination	14.0-16.0	96.8	91.3	83.0	71.2	59.9	52.1	26.6
Enhanced Coordination	12.0-14.0	96.9	80.2	68.5	58.6	48.6	40.6	18.8
Enhanced Coordination	10.0-12.0	95.4	66.4	56.3	45.1	35.8	28.4	14.4
Enhanced Coordination	4.5-10.0	85.9	53.8	42.9	32.9	25.3	19.4	7.6

Alternative	Flow Category	Max (% Full)	90% (% Full)	75% (% Full)	50% (% Full)	25% (% Full)	10% (% Full)	Min (% Full)
Max. Operational Flexibility	16.0-31.1	96.9	95.6	94.2	88.7	81.2	67.3	44.9
Max. Operational Flexibility	14.0-16.0	97.4	93.4	86.2	74.9	60.1	50.6	28.4
Max. Operational Flexibility	12.0-14.0	96.8	84.0	72.9	59.8	47.2	39.1	20.3
Max. Operational Flexibility	10.0-12.0	96.3	70.9	59.3	44.4	34.8	29.7	17.7
Max. Operational Flexibility	4.5-10.0	90.0	57.9	43.7	32.6	26.4	21.1	9.6
Supply Driven (LB Priority)	16.0-31.1	96.9	95.2	91.7	84.2	74.7	62.1	35.2
Supply Driven (LB Priority)	14.0-16.0	96.6	87.6	79.1	67.8	54.1	43.9	18.8
Supply Driven (LB Priority)	12.0-14.0	96.6	75.6	64.8	52.9	41.1	31.0	10.6
Supply Driven (LB Priority)	10.0-12.0	94.7	62.3	51.8	38.9	26.6	18.7	8.9
Supply Driven (LB Priority)	4.5-10.0	77.9	49.2	38.7	27.3	17.1	11.7	6.2
Supply Driven (LB Pro Rata)	16.0-31.1	96.9	95.2	91.9	84.7	76.0	65.0	39.6
Supply Driven (LB Pro Rata)	14.0-16.0	96.6	87.9	79.9	69.5	57.0	47.9	19.0
Supply Driven (LB Pro Rata)	12.0-14.0	96.7	76.4	66.0	55.4	44.5	35.3	10.4
Supply Driven (LB Pro Rata)	10.0-12.0	95.3	63.6	53.6	42.0	30.6	20.7	8.7
Supply Driven (LB Pro Rata)	4.5-10.0	79.9	50.6	40.6	29.5	19.9	12.3	6.1
Representative Preferred	16.0-31.1	96.9	95.1	90.7	82.5	72.2	60.2	34.5
Representative Preferred	14.0-16.0	96.6	85.9	77.1	65.3	52.3	43.5	21.9
Representative Preferred	12.0-14.0	96.5	73.3	61.3	50.8	39.6	31.6	14
Representative Preferred	10.0-12.0	94.0	58.8	48.4	36.9	27.0	21.6	11.4
Representative Preferred	4.5-10.0	76.1	46.2	36.2	26.5	18.5	13.0	6.1

Table TA 3-14
WY Releases from Glen Canyon Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	38.09	14.79	11.63	9.00	8.23	8.23	6.45
CCS Comparative Baseline	14.0-16.0	24.28	10.81	9.00	9.00	8.23	7.48	6.00
CCS Comparative Baseline	12.0-14.0	28.14	9.00	9.00	8.23	7.48	6.89	5.36
CCS Comparative Baseline	10.0-12.0	17.22	9.16	8.23	7.48	6.37	6.00	4.15
CCS Comparative Baseline	4.5-10.0	9.50	9.00	7.66	6.41	5.73	4.79	2.42
No Action	16.0-31.1	38.13	15.25	11.82	8.40	8.23	8.23	6.27
No Action	14.0-16.0	24.50	11.35	8.23	8.23	8.23	8.23	6.15
No Action	12.0-14.0	28.49	8.23	8.23	8.23	8.23	7.20	5.11
No Action	10.0-12.0	18.89	8.23	8.23	8.23	6.49	5.93	4.06
No Action	4.5-10.0	8.32	8.23	8.23	6.36	5.33	4.58	2.76
Basic Coordination	16.0-31.1	38.09	14.97	11.48	9.50	9.50	8.93	8.23
Basic Coordination	14.0-16.0	22.88	9.58	9.50	8.64	8.23	8.23	6.92
Basic Coordination	12.0-14.0	26.99	9.29	8.23	8.23	7.86	7.30	5.68
Basic Coordination	10.0-12.0	17.59	8.23	7.92	7.20	7.00	6.31	4.37
Basic Coordination	4.5-10.0	8.23	7.10	7.00	6.92	5.72	4.73	2.42

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Enhanced Coordination	16.0-31.1	38.44	15.42	11.63	10.24	10.16	10.09	6.74
Enhanced Coordination	14.0-16.0	27.13	10.46	10.16	9.79	8.40	7.41	4.74
Enhanced Coordination	12.0-14.0	29.33	10.04	8.92	7.95	6.90	6.02	4.74
Enhanced Coordination	10.0-12.0	19.84	8.55	7.97	7.05	5.93	4.74	4.74
Enhanced Coordination	4.5-10.0	9.49	7.58	6.29	5.11	4.74	4.74	2.70
Max. Operational Flexibility	16.0-31.1	38.59	15.78	12.11	10.44	10.11	9.49	8.05
Max. Operational Flexibility	14.0-16.0	25.97	10.81	9.98	9.31	8.74	8.34	6.89
Max. Operational Flexibility	12.0-14.0	28.85	9.21	8.67	8.17	7.70	7.23	5.14
Max. Operational Flexibility	10.0-12.0	19.31	8.13	7.63	7.10	6.64	6.18	4.07
Max. Operational Flexibility	4.5-10.0	8.55	6.54	6.01	5.61	5.06	4.61	3.62
Supply Driven (LB Priority)	16.0-31.1	38.29	14.14	12.00	11.63	10.91	10.61	10.40
Supply Driven (LB Priority)	14.0-16.0	21.64	10.28	10.03	9.65	9.34	9.19	7.63
Supply Driven (LB Priority)	12.0-14.0	27.98	8.97	8.75	8.41	8.08	7.88	6.22
Supply Driven (LB Priority)	10.0-12.0	18.53	7.67	7.48	7.12	6.80	6.57	5.93
Supply Driven (LB Priority)	4.5-10.0	7.56	6.49	6.42	6.04	5.62	5.18	3.23
Supply Driven (LB Pro Rata)	16.0-31.1	38.29	14.14	12.00	11.63	10.91	10.61	10.40
Supply Driven (LB Pro Rata)	14.0-16.0	21.64	10.28	10.03	9.65	9.34	9.19	7.63
Supply Driven (LB Pro Rata)	12.0-14.0	27.98	8.97	8.75	8.41	8.08	7.88	6.22
Supply Driven (LB Pro Rata)	10.0-12.0	18.53	7.67	7.48	7.12	6.80	6.57	5.93
Supply Driven (LB Pro Rata)	4.5-10.0	7.56	6.49	6.42	6.04	5.62	5.18	3.23
Representative Preferred	16.0-31.1	38.29	14.47	12.00	12.00	10.70	9.05	8.23
Representative Preferred	14.0-16.0	22.85	11.36	9.94	8.23	8.23	8.23	6.97
Representative Preferred	12.0-14.0	28.46	8.23	8.23	8.23	8.23	7.50	5.00
Representative Preferred	10.0-12.0	18.97	8.23	8.19	7.20	6.47	6.00	5.00
Representative Preferred	4.5-10.0	8.23	6.65	6.00	6.00	5.45	5.00	2.42

NOTE: Releases colored blue highlight Glen Canyon Dam's median release of 8.23 maf. Releases colored red are at or below the smallest releases allowable of 4.73 maf in accordance with LTEMP (Reclamation 2016).

Table TA 3-15
10-Year Releases from Glen Canyon Dam

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	174.0	119.6	106.6	93.0	83.3	79.4	60.4
CCS Comparative Baseline	14.0-16.0	154.5	102.8	90.4	83.5	79.5	76.3	58.6
CCS Comparative Baseline	12.0-14.0	145.4	92.2	85.4	80.4	77.3	72.0	48.2
CCS Comparative Baseline	10.0-12.0	134.5	86.7	80.9	77.7	71.4	64.0	46.3
CCS Comparative Baseline	4.5-10.0	132.9	83.5	79.5	74.5	65.2	56.4	38.5
No Action	16.0-31.1	174.6	120.6	107.8	93.3	82.3	77.8	58.8
No Action	14.0-16.0	156.8	103.8	91.0	82.3	79.2	74.6	59.4
No Action	12.0-14.0	145.5	92.3	82.3	80.8	77.0	70.7	48.7
No Action	10.0-12.0	135.3	84.7	82.0	77.8	70.4	63.5	46.3
No Action	4.5-10.0	135.3	82.3	80.6	74.2	64.2	55.8	40.4

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Basic Coordination	16.0-31.1	173.9	120.1	107.7	93.6	82.4	77.6	57.7
Basic Coordination	14.0-16.0	156.3	104.6	93.0	82.9	77.5	74.0	57.5
Basic Coordination	12.0-14.0	148.6	95.5	85.8	79.0	75.2	70.2	47.8
Basic Coordination	10.0-12.0	135.3	87.9	80.3	76.2	71.2	64.2	45.4
Basic Coordination	4.5-10.0	131.8	84.2	79.5	74.5	65.8	56.8	38.4
Enhanced Coordination	16.0-31.1	177.0	123.9	111.0	97.3	84.8	77.9	60.8
Enhanced Coordination	14.0-16.0	160.5	108.3	96.4	83.3	76.4	71.6	59.3
Enhanced Coordination	12.0-14.0	153.7	97.1	84.7	77.4	72.0	67.1	46.2
Enhanced Coordination	10.0-12.0	139.2	85.6	77.2	72.2	66.3	61.4	44.0
Enhanced Coordination	4.5-10.0	135.6	78.9	77.6	69.1	61.6	54.5	42.3
Max. Operational Flexibility	16.0-31.1	178.7	125.1	112.5	98.1	85.6	77.8	59.6
Max. Operational Flexibility	14.0-16.0	161.0	108.8	97.0	84.9	76.8	72.2	57.3
Max. Operational Flexibility	12.0-14.0	152.4	98.6	87.7	78.9	72.8	67.4	47.8
Max. Operational Flexibility	10.0-12.0	138.8	89.8	80.5	74.0	67.8	62.1	45.6
Max. Operational Flexibility	4.5-10.0	133.7	83.5	77.7	70.8	62.6	55.0	40.7
Supply Driven (LB Priority)	16.0-31.1	174.7	122.8	109.8	97.5	87.1	80.8	62.0
Supply Driven (LB Priority)	14.0-16.0	161.0	107.4	96.9	87.4	79.6	75.8	63.8
Supply Driven (LB Priority)	12.0-14.0	152.4	98.0	89.0	81.7	76.0	71.0	51.9
Supply Driven (LB Priority)	10.0-12.0	138.9	90.2	82.4	76.4	71.2	66.1	51.4
Supply Driven (LB Priority)	4.5-10.0	132.7	85.0	79.0	73.5	66.6	60.4	46.8
Supply Driven (LB Pro Rata)	16.0-31.1	174.7	122.8	109.8	97.5	87.1	80.8	62.0
Supply Driven (LB Pro Rata)	14.0-16.0	161.0	107.4	96.9	87.4	79.6	75.8	63.8
Supply Driven (LB Pro Rata)	12.0-14.0	152.4	98.0	89.0	81.7	76.0	71.0	51.9
Supply Driven (LB Pro Rata)	10.0-12.0	138.9	90.2	82.4	76.4	71.2	66.1	51.4
Supply Driven (LB Pro Rata)	4.5-10.0	132.7	85.0	79.0	73.5	66.6	60.4	46.8
Representative Preferred	16.0-31.1	175.7	123.5	110.8	97.7	85.2	78.4	58.8
Representative Preferred	14.0-16.0	160.9	107.8	96.6	84.4	77.0	72.8	58.0
Representative Preferred	12.0-14.0	152.3	98.2	87.6	78.8	74.0	69.0	47.8
Representative Preferred	10.0-12.0	139.6	90.0	80.4	74.8	69.2	63.1	45.1
Representative Preferred	4.5-10.0	133.4	84.5	78.5	72.5	64.4	56.5	40.0

Table TA 3-16
Cumulative 10-Year Lee Ferry Flow Volume (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	175.7	121.3	108.2	94.6	84.9	80.9	62.0
CCS Comparative Baseline	14.0-16.0	156.2	104.4	92.1	85.1	81.1	77.9	60.3
CCS Comparative Baseline	12.0-14.0	147.0	93.8	87.0	81.9	78.8	73.6	49.8
CCS Comparative Baseline	10.0-12.0	136.2	88.3	82.5	79.1	73.0	65.6	47.9
CCS Comparative Baseline	4.5-10.0	134.6	85.1	81.0	76.0	66.8	58.0	40.1

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
No Action	16.0-31.1	176.3	122.2	109.5	95.0	83.9	79.4	60.4
No Action	14.0-16.0	158.5	105.4	92.7	83.9	80.5	76.3	61.1
No Action	12.0-14.0	147.2	94.0	84.0	82.3	78.6	72.3	50.3
No Action	10.0-12.0	137.0	86.4	83.6	79.3	72.0	65.2	47.9
No Action	4.5-10.0	137.0	84.0	82.0	75.7	65.8	57.4	42.0
Basic Coordination	16.0-31.1	175.6	121.8	109.3	95.2	84.0	79.2	59.4
Basic Coordination	14.0-16.0	157.9	106.3	94.6	84.5	78.9	75.6	59.2
Basic Coordination	12.0-14.0	150.3	97.2	87.5	80.6	76.8	71.8	49.4
Basic Coordination	10.0-12.0	136.9	89.6	82.0	77.7	72.7	65.8	47.0
Basic Coordination	4.5-10.0	133.4	85.8	80.9	76.0	67.3	58.5	40.0
Enhanced Coordination	16.0-31.1	178.7	125.6	112.6	98.9	86.3	79.4	62.5
Enhanced Coordination	14.0-16.0	162.2	110.0	98.1	85.0	77.9	73.3	61.0
Enhanced Coordination	12.0-14.0	155.3	98.8	86.4	78.9	73.5	68.7	47.8
Enhanced Coordination	10.0-12.0	140.9	87.3	78.8	73.8	67.9	63.0	45.6
Enhanced Coordination	4.5-10.0	137.3	80.6	79.0	70.6	63.2	56.1	43.9
Max. Operational Flexibility	16.0-31.1	180.4	126.8	114.2	99.8	87.2	79.3	61.2
Max. Operational Flexibility	14.0-16.0	162.6	110.4	98.7	86.5	78.3	73.7	59.0
Max. Operational Flexibility	12.0-14.0	154.1	100.2	89.4	80.6	74.4	68.9	49.4
Max. Operational Flexibility	10.0-12.0	140.4	91.5	82.1	75.5	69.4	63.7	47.2
Max. Operational Flexibility	4.5-10.0	135.4	85.2	79.1	72.4	64.2	56.7	42.3
Supply Driven (LB Priority)	16.0-31.1	176.4	124.4	111.4	99.1	88.6	82.2	63.6
Supply Driven (LB Priority)	14.0-16.0	162.7	109.0	98.6	89.1	81.1	77.3	65.4
Supply Driven (LB Priority)	12.0-14.0	154.1	99.6	90.7	83.4	77.5	72.6	53.5
Supply Driven (LB Priority)	10.0-12.0	140.6	91.8	84.0	78.0	72.7	67.7	53.0
Supply Driven (LB Priority)	4.5-10.0	134.4	86.7	80.4	74.9	68.2	62.0	48.4
Supply Driven (LB Pro Rata)	16.0-31.1	176.4	124.4	111.4	99.1	88.6	82.2	63.6
Supply Driven (LB Pro Rata)	14.0-16.0	162.7	109.0	98.6	89.1	81.1	77.3	65.4
Supply Driven (LB Pro Rata)	12.0-14.0	154.1	99.6	90.7	83.4	77.5	72.6	53.5
Supply Driven (LB Pro Rata)	10.0-12.0	140.6	91.8	84.0	78.0	72.7	67.7	53.0
Supply Driven (LB Pro Rata)	4.5-10.0	134.4	86.7	80.4	74.9	68.2	62.0	48.4
Representative Preferred	16.0-31.1	177.4	125.2	112.5	99.3	86.7	79.9	60.4
Representative Preferred	14.0-16.0	162.6	109.4	98.2	86.0	78.6	74.3	59.7
Representative Preferred	12.0-14.0	154.0	99.9	89.3	80.4	75.5	70.6	49.4
Representative Preferred	10.0-12.0	141.2	91.6	82.1	76.4	70.7	64.7	46.7
Representative Preferred	4.5-10.0	135.1	86.1	79.9	73.9	66.0	58.1	41.6

Table TA 3-17
Compact Point 10-Year Volume Relative to 75.0 maf[17]

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	100.7	46.3	33.2	19.6	9.9	5.9	-13.0
CCS Comparative Baseline	14.0-16.0	81.2	29.4	17.1	10.1	6.1	2.9	-14.7
CCS Comparative Baseline	12.0-14.0	72.0	18.8	12.0	6.9	3.8	-1.4	-25.2
CCS Comparative Baseline	10.0-12.0	61.2	13.3	7.5	4.1	-2.0	-9.4	-27.1
CCS Comparative Baseline	4.5-10.0	59.6	10.1	6.0	1.0	-8.2	-17.0	-34.9
No Action	16.0-31.1	101.3	47.2	34.5	20.0	8.9	4.4	-14.6
No Action	14.0-16.0	83.5	30.4	17.7	8.9	5.5	1.3	-13.9
No Action	12.0-14.0	72.2	19.0	9.0	7.3	3.6	-2.7	-24.7
No Action	10.0-12.0	62.0	11.4	8.6	4.3	-3.0	-9.8	-27.1
No Action	4.5-10.0	62.0	9.0	7.0	0.7	-9.2	-17.6	-33.0
Basic Coordination	16.0-31.1	100.6	46.8	34.3	20.2	9.0	4.2	-15.6
Basic Coordination	14.0-16.0	82.9	31.3	19.6	9.5	3.9	0.6	-15.8
Basic Coordination	12.0-14.0	75.3	22.2	12.5	5.6	1.8	-3.2	-25.6
Basic Coordination	10.0-12.0	61.9	14.6	7.0	2.7	-2.3	-9.2	-28.0
Basic Coordination	4.5-10.0	58.4	10.8	5.9	1.0	-7.7	-16.5	-35.0
Enhanced Coordination	16.0-31.1	103.7	50.6	37.6	23.9	11.3	4.4	-12.5
Enhanced Coordination	14.0-16.0	87.2	35.0	23.1	10.0	2.9	-1.7	-14.0
Enhanced Coordination	12.0-14.0	80.3	23.8	11.4	3.9	-1.5	-6.3	-27.2
Enhanced Coordination	10.0-12.0	65.9	12.3	3.8	-1.2	-7.1	-12.0	-29.4
Enhanced Coordination	4.5-10.0	62.3	5.6	4.0	-4.4	-11.8	-18.9	-31.1
Max. Operational Flexibility	16.0-31.1	105.4	51.8	39.2	24.8	12.2	4.3	-13.8
Max. Operational Flexibility	14.0-16.0	87.6	35.4	23.7	11.5	3.3	-1.3	-16.0
Max. Operational Flexibility	12.0-14.0	79.1	25.2	14.4	5.6	-0.6	-6.1	-25.6
Max. Operational Flexibility	10.0-12.0	65.4	16.5	7.1	0.5	-5.6	-11.3	-27.8
Max. Operational Flexibility	4.5-10.0	60.4	10.2	4.1	-2.6	-10.8	-18.3	-32.7
Supply Driven (LB Priority)	16.0-31.1	101.4	49.4	36.4	24.1	13.6	7.2	-11.4
Supply Driven (LB Priority)	14.0-16.0	87.7	34.0	23.6	14.1	6.1	2.3	-9.6
Supply Driven (LB Priority)	12.0-14.0	79.1	24.6	15.7	8.4	2.5	-2.4	-21.5
Supply Driven (LB Priority)	10.0-12.0	65.6	16.8	9.0	3.0	-2.3	-7.3	-22.0
Supply Driven (LB Priority)	4.5-10.0	59.4	11.7	5.4	-0.1	-6.8	-13.0	-26.6
Supply Driven (LB Pro Rata)	16.0-31.1	101.4	49.4	36.4	24.1	13.6	7.2	-11.4
Supply Driven (LB Pro Rata)	14.0-16.0	87.7	34.0	23.6	14.1	6.1	2.3	-9.6
Supply Driven (LB Pro Rata)	12.0-14.0	79.1	24.6	15.7	8.4	2.5	-2.4	-21.5
Supply Driven (LB Pro Rata)	10.0-12.0	65.6	16.8	9.0	3.0	-2.3	-7.3	-22.0
Supply Driven (LB Pro Rata)	4.5-10.0	59.4	11.7	5.4	-0.1	-6.8	-13.0	-26.6

[17] Positive numbers indicate a volume is above 75.0 maf and negative numbers mean a volume is below 75.0 maf

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Representative Preferred	16.0-31.1	102.4	50.2	37.5	24.3	11.7	4.9	-14.6
Representative Preferred	14.0-16.0	87.6	34.4	23.2	11.0	3.6	-0.7	-15.3
Representative Preferred	12.0-14.0	79.0	24.9	14.3	5.4	0.5	-4.4	-25.6
Representative Preferred	10.0-12.0	66.2	16.6	7.1	1.4	-4.3	-10.3	-28.3
Representative Preferred	4.5-10.0	60.1	11.1	4.9	-1.1	-9.0	-16.9	-33.4

Table TA 3-18
Compact Point 10-Year Volume Relative to 82.5 maf[18]

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	93.2	38.8	25.7	12.1	2.4	-1.6	-20.5
CCS Comparative Baseline	14.0-16.0	73.7	21.9	9.6	2.6	-1.4	-4.6	-22.2
CCS Comparative Baseline	12.0-14.0	64.5	11.3	4.5	-0.6	-3.7	-8.9	-32.7
CCS Comparative Baseline	10.0-12.0	53.7	5.8	0.0	-3.4	-9.5	-16.9	-34.6
CCS Comparative Baseline	4.5-10.0	52.1	2.6	-1.5	-6.5	-15.7	-24.5	-42.4
No Action	16.0-31.1	93.8	39.7	27.0	12.5	1.4	-3.1	-22.1
No Action	14.0-16.0	76.0	22.9	10.2	1.4	-2.0	-6.2	-21.4
No Action	12.0-14.0	64.7	11.5	1.5	-0.2	-3.9	-10.2	-32.2
No Action	10.0-12.0	54.5	3.9	1.1	-3.2	-10.5	-17.3	-34.6
No Action	4.5-10.0	54.5	1.5	-0.5	-6.8	-16.7	-25.1	-40.5
Basic Coordination	16.0-31.1	93.1	39.3	26.8	12.7	1.5	-3.3	-23.1
Basic Coordination	14.0-16.0	75.4	23.8	12.1	2.0	-3.6	-6.9	-23.3
Basic Coordination	12.0-14.0	67.8	14.7	5.0	-1.9	-5.7	-10.7	-33.1
Basic Coordination	10.0-12.0	54.4	7.1	-0.5	-4.8	-9.8	-16.7	-35.5
Basic Coordination	4.5-10.0	50.9	3.3	-1.6	-6.5	-15.2	-24.0	-42.5
Enhanced Coordination	16.0-31.1	96.2	43.1	30.1	16.4	3.8	-3.1	-20.0
Enhanced Coordination	14.0-16.0	79.7	27.5	15.6	2.5	-4.6	-9.2	-21.5
Enhanced Coordination	12.0-14.0	72.8	16.3	3.9	-3.6	-9.0	-13.8	-34.7
Enhanced Coordination	10.0-12.0	58.4	4.8	-3.7	-8.7	-14.6	-19.5	-36.9
Enhanced Coordination	4.5-10.0	54.8	-1.9	-3.5	-11.9	-19.3	-26.4	-38.6
Max. Operational Flexibility	16.0-31.1	97.9	44.3	31.7	17.3	4.7	-3.2	-21.3
Max. Operational Flexibility	14.0-16.0	80.1	27.9	16.2	4.0	-4.2	-8.8	-23.5
Max. Operational Flexibility	12.0-14.0	71.6	17.7	6.9	-1.9	-8.1	-13.6	-33.1
Max. Operational Flexibility	10.0-12.0	57.9	9.0	-0.4	-7.0	-13.1	-18.8	-35.3
Max. Operational Flexibility	4.5-10.0	52.9	2.7	-3.4	-10.1	-18.3	-25.8	-40.2
Supply Driven (LB Priority)	16.0-31.1	93.9	41.9	28.9	16.6	6.1	-0.3	-18.9
Supply Driven (LB Priority)	14.0-16.0	80.2	26.5	16.1	6.6	-1.4	-5.2	-17.1
Supply Driven (LB Priority)	12.0-14.0	71.6	17.1	8.2	0.9	-5.0	-9.9	-29.0
Supply Driven (LB Priority)	10.0-12.0	58.1	9.3	1.5	-4.5	-9.8	-14.8	-29.5
Supply Driven (LB Priority)	4.5-10.0	51.9	4.2	-2.1	-7.6	-14.3	-20.5	-34.1

[18] Positive numbers indicate a volume is above 82.5 maf and negative numbers mean a volume is below 82.5 maf

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Pro Rata)	16.0-31.1	93.9	41.9	28.9	16.6	6.1	-0.3	-18.9
Supply Driven (LB Pro Rata)	14.0-16.0	80.2	26.5	16.1	6.6	-1.4	-5.2	-17.1
Supply Driven (LB Pro Rata)	12.0-14.0	71.6	17.1	8.2	0.9	-5.0	-9.9	-29.0
Supply Driven (LB Pro Rata)	10.0-12.0	58.1	9.3	1.5	-4.5	-9.8	-14.8	-29.5
Supply Driven (LB Pro Rata)	4.5-10.0	51.9	4.2	-2.1	-7.6	-14.3	-20.5	-34.1
Representative Preferred	16.0-31.1	94.9	42.7	30.0	16.8	4.2	-2.6	-22.1
Representative Preferred	14.0-16.0	80.1	26.9	15.7	3.5	-3.9	-8.2	-22.8
Representative Preferred	12.0-14.0	71.5	17.4	6.8	-2.1	-7.0	-11.9	-33.1
Representative Preferred	10.0-12.0	58.7	9.1	-0.4	-6.1	-11.8	-17.8	-35.8
Representative Preferred	4.5-10.0	52.6	3.6	-2.6	-8.6	-16.5	-24.4	-40.9

Table TA 3-19
CY Releases from Hoover Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	37.94	12.15	10.05	9.39	8.70	8.36	6.85
CCS Comparative Baseline	14.0-16.0	22.33	9.67	9.21	8.68	8.28	7.96	6.19
CCS Comparative Baseline	12.0-14.0	21.35	9.29	8.77	8.32	7.96	7.64	5.81
CCS Comparative Baseline	10.0-12.0	13.17	8.94	8.44	7.93	7.30	6.53	4.28
CCS Comparative Baseline	4.5-10.0	10.36	8.67	8.28	7.47	6.12	5.14	2.64
No Action	16.0-31.1	37.85	12.11	10.08	9.28	8.77	8.50	7.20
No Action	14.0-16.0	22.37	9.53	9.17	8.77	8.54	8.27	7.10
No Action	12.0-14.0	22.68	9.26	8.89	8.63	8.30	7.86	5.19
No Action	10.0-12.0	13.27	9.16	8.74	8.09	7.28	6.48	3.75
No Action	4.5-10.0	10.16	9.22	8.69	7.21	5.83	5.04	2.88
Basic Coordination	16.0-31.1	38.04	12.86	10.63	9.19	8.17	7.84	6.37
Basic Coordination	14.0-16.0	21.75	9.51	9.01	8.26	7.92	7.70	6.27
Basic Coordination	12.0-14.0	22.02	9.14	8.41	8.03	7.76	7.45	5.83
Basic Coordination	10.0-12.0	12.87	8.64	8.16	7.80	7.36	6.86	4.20
Basic Coordination	4.5-10.0	9.99	8.47	8.10	7.66	6.46	5.28	2.61
Enhanced Coordination	16.0-31.1	38.33	14.19	11.03	9.38	8.70	7.92	5.77
Enhanced Coordination	14.0-16.0	23.36	9.87	9.16	8.55	7.68	7.20	5.71
Enhanced Coordination	12.0-14.0	24.08	9.12	8.37	7.58	7.09	6.59	4.93
Enhanced Coordination	10.0-12.0	14.35	8.09	7.54	6.93	6.39	6.03	4.32
Enhanced Coordination	4.5-10.0	9.76	7.54	7.06	6.48	6.04	5.20	2.92
Max. Operational Flexibility	16.0-31.1	38.48	14.57	11.23	9.34	8.30	7.53	5.67
Max. Operational Flexibility	14.0-16.0	23.91	10.09	9.02	8.28	7.68	7.21	5.79
Max. Operational Flexibility	12.0-14.0	24.99	8.76	8.26	7.78	7.31	6.95	4.98
Max. Operational Flexibility	10.0-12.0	16.69	8.18	7.79	7.29	6.67	6.15	4.70
Max. Operational Flexibility	4.5-10.0	8.99	7.83	7.30	6.40	5.79	5.34	3.66

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Priority)	16.0-31.1	38.25	13.37	11.32	10.22	8.09	7.27	5.43
Supply Driven (LB Priority)	14.0-16.0	20.06	10.02	9.43	8.25	7.53	7.05	5.46
Supply Driven (LB Priority)	12.0-14.0	17.32	9.32	8.48	7.74	7.30	6.94	4.87
Supply Driven (LB Priority)	10.0-12.0	10.79	8.54	7.94	7.48	7.03	6.64	4.75
Supply Driven (LB Priority)	4.5-10.0	10.27	8.16	7.75	7.24	6.71	5.91	3.53
Supply Driven (LB Pro Rata)	16.0-31.1	38.25	13.47	11.37	10.38	8.01	7.24	5.49
Supply Driven (LB Pro Rata)	14.0-16.0	20.06	10.01	9.44	8.16	7.45	6.93	5.35
Supply Driven (LB Pro Rata)	12.0-14.0	18.68	9.35	8.42	7.65	7.19	6.79	5.14
Supply Driven (LB Pro Rata)	10.0-12.0	11.57	8.46	7.78	7.36	6.92	6.54	4.72
Supply Driven (LB Pro Rata)	4.5-10.0	10.21	7.94	7.55	7.12	6.68	5.95	3.48
Representative Preferred	16.0-31.1	38.25	13.02	11.26	9.78	8.25	7.69	5.76
Representative Preferred	14.0-16.0	22.08	10.07	9.42	8.27	7.79	7.39	5.63
Representative Preferred	12.0-14.0	20.09	9.41	8.52	7.89	7.55	7.11	4.88
Representative Preferred	10.0-12.0	10.59	8.61	8.03	7.61	6.83	6.11	4.13
Representative Preferred	4.5-10.0	10.33	8.16	7.77	6.94	5.89	5.5	2.55

Table TA 3-20
CY Releases from Davis Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	37.6	12.1	9.9	9.3	8.6	8.3	7.1
CCS Comparative Baseline	14.0-16.0	22.5	9.6	9.1	8.6	8.2	7.9	6.4
CCS Comparative Baseline	12.0-14.0	21.9	9.2	8.7	8.2	7.8	7.6	5.7
CCS Comparative Baseline	10.0-12.0	13.3	8.8	8.3	7.9	7.2	6.5	4.3
CCS Comparative Baseline	4.5-10.0	10.1	8.6	8.2	7.4	6.0	5.0	2.5
No Action	16.0-31.1	37.5	12.1	10.0	9.2	8.7	8.4	7.6
No Action	14.0-16.0	22.6	9.4	9.1	8.7	8.4	8.2	7.3
No Action	12.0-14.0	23.2	9.2	8.8	8.5	8.2	7.8	5.2
No Action	10.0-12.0	13.4	9.0	8.7	8.1	7.2	6.3	3.7
No Action	4.5-10.0	9.9	9.1	8.6	7.1	5.7	4.9	2.8
Basic Coordination	16.0-31.1	37.7	12.9	10.6	9.1	8.1	7.7	6.8
Basic Coordination	14.0-16.0	21.8	9.4	8.9	8.1	7.8	7.6	6.5
Basic Coordination	12.0-14.0	22.6	9.1	8.3	7.9	7.7	7.4	6.1
Basic Coordination	10.0-12.0	13.0	8.5	8.0	7.7	7.3	6.8	3.9
Basic Coordination	4.5-10.0	9.8	8.3	8.0	7.6	6.4	5.2	2.6
Enhanced Coordination	16.0-31.1	38.0	14.3	10.9	9.3	8.6	7.9	6.2
Enhanced Coordination	14.0-16.0	23.4	9.8	9.0	8.5	7.5	7.1	5.8
Enhanced Coordination	12.0-14.0	24.6	9.0	8.3	7.4	7.0	6.5	5.4
Enhanced Coordination	10.0-12.0	14.5	8.0	7.4	6.8	6.3	6.0	4.3
Enhanced Coordination	4.5-10.0	9.5	7.4	6.9	6.4	6.0	5.2	2.9

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Max. Operational Flexibility	16.0-31.1	38.2	14.6	11.1	9.2	8.2	7.4	6.0
Max. Operational Flexibility	14.0-16.0	23.8	10.1	8.9	8.1	7.6	7.2	6.0
Max. Operational Flexibility	12.0-14.0	25.5	8.7	8.1	7.6	7.2	6.9	5.4
Max. Operational Flexibility	10.0-12.0	16.8	8.1	7.7	7.2	6.6	6.1	4.8
Max. Operational Flexibility	4.5-10.0	8.7	7.7	7.2	6.3	5.7	5.3	3.6
Supply Driven (LB Priority)	16.0-31.1	37.9	13.5	11.3	10.1	8.0	7.2	5.8
Supply Driven (LB Priority)	14.0-16.0	20.1	9.9	9.3	8.1	7.4	7.0	5.8
Supply Driven (LB Priority)	12.0-14.0	17.6	9.2	8.4	7.6	7.2	6.9	5.3
Supply Driven (LB Priority)	10.0-12.0	10.9	8.4	7.8	7.3	6.9	6.6	5.2
Supply Driven (LB Priority)	4.5-10.0	10.0	8.1	7.6	7.1	6.7	5.9	3.4
Supply Driven (LB Pro Rata)	16.0-31.1	37.9	13.6	11.3	10.3	7.9	7.1	5.7
Supply Driven (LB Pro Rata)	14.0-16.0	20.1	10.0	9.4	8.0	7.3	6.9	5.6
Supply Driven (LB Pro Rata)	12.0-14.0	19.0	9.2	8.4	7.5	7.1	6.8	5.6
Supply Driven (LB Pro Rata)	10.0-12.0	11.5	8.4	7.7	7.2	6.8	6.5	5.1
Supply Driven (LB Pro Rata)	4.5-10.0	10.0	7.8	7.4	7.0	6.6	5.9	3.3
Representative Preferred	16.0-31.1	37.9	13.1	11.2	9.7	8.1	7.6	6.0
Representative Preferred	14.0-16.0	22.2	9.9	9.3	8.2	7.6	7.4	5.7
Representative Preferred	12.0-14.0	20.6	9.3	8.4	7.8	7.5	7.0	5.2
Representative Preferred	10.0-12.0	10.5	8.5	7.9	7.5	6.8	6.0	4.5
Representative Preferred	4.5-10.0	10.1	8.0	7.6	6.9	5.8	5.5	2.5

Table TA 3-21
CY Releases from Parker Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	34.8	9.2	7.0	6.7	6.5	6.4	5.9
CCS Comparative Baseline	14.0-16.0	19.9	6.9	6.7	6.6	6.4	6.3	5.8
CCS Comparative Baseline	12.0-14.0	18.7	6.8	6.6	6.5	6.3	6.2	4.8
CCS Comparative Baseline	10.0-12.0	10.6	6.7	6.5	6.3	6.1	5.6	3.6
CCS Comparative Baseline	4.5-10.0	7.2	6.6	6.3	6.1	5.2	4.4	2.0
No Action	16.0-31.1	34.4	8.8	7.0	6.8	6.6	6.5	6.1
No Action	14.0-16.0	19.6	7.0	6.8	6.6	6.5	6.4	5.8
No Action	12.0-14.0	19.7	6.8	6.7	6.6	6.4	6.3	4.4
No Action	10.0-12.0	10.6	6.8	6.6	6.4	6.0	5.3	3.2
No Action	4.5-10.0	7.3	6.7	6.5	6.0	4.9	4.3	2.4
Basic Coordination	16.0-31.1	34.6	9.8	7.2	6.7	6.5	6.3	5.9
Basic Coordination	14.0-16.0	18.6	6.9	6.7	6.6	6.4	6.3	5.9
Basic Coordination	12.0-14.0	19.1	6.8	6.6	6.5	6.3	6.2	5.3
Basic Coordination	10.0-12.0	10.2	6.7	6.5	6.4	6.2	5.9	3.2
Basic Coordination	4.5-10.0	7.2	6.6	6.4	6.3	5.5	4.5	2.1

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Enhanced Coordination	16.0-31.1	34.9	11.2	7.6	6.7	6.3	6.0	5.0
Enhanced Coordination	14.0-16.0	20.1	7.1	6.6	6.3	5.6	5.3	4.5
Enhanced Coordination	12.0-14.0	21.1	6.6	6.2	5.5	5.1	4.8	4.1
Enhanced Coordination	10.0-12.0	12.0	5.9	5.5	5.0	4.6	4.4	3.3
Enhanced Coordination	4.5-10.0	6.9	5.4	5.0	4.6	4.4	4.1	2.3
Max. Operational Flexibility	16.0-31.1	35.0	11.5	7.8	6.8	6.4	6.1	5.6
Max. Operational Flexibility	14.0-16.0	20.6	7.4	6.7	6.5	6.2	6.0	5.6
Max. Operational Flexibility	12.0-14.0	21.7	6.7	6.5	6.3	6.1	5.9	5.4
Max. Operational Flexibility	10.0-12.0	14.5	6.5	6.3	6.1	5.8	5.6	4.3
Max. Operational Flexibility	4.5-10.0	7.0	6.3	6.1	5.7	5.3	5.0	3.0
Supply Driven (LB Priority)	16.0-31.1	34.8	10.5	8.2	7.1	6.4	6.1	5.6
Supply Driven (LB Priority)	14.0-16.0	16.9	7.1	6.8	6.4	6.2	6.0	5.6
Supply Driven (LB Priority)	12.0-14.0	14.3	6.8	6.5	6.3	6.1	5.9	5.6
Supply Driven (LB Priority)	10.0-12.0	8.4	6.6	6.4	6.2	6.0	5.9	5.2
Supply Driven (LB Priority)	4.5-10.0	7.2	6.5	6.3	6.1	5.8	5.2	2.9
Supply Driven (LB Pro Rata)	16.0-31.1	34.8	10.6	8.2	7.3	6.0	5.6	5.0
Supply Driven (LB Pro Rata)	14.0-16.0	16.9	7.1	6.8	6.1	5.7	5.4	4.9
Supply Driven (LB Pro Rata)	12.0-14.0	15.6	6.7	6.3	5.8	5.5	5.3	4.8
Supply Driven (LB Pro Rata)	10.0-12.0	9.1	6.3	5.8	5.5	5.3	5.2	4.6
Supply Driven (LB Pro Rata)	4.5-10.0	7.2	5.9	5.7	5.4	5.2	4.9	2.8
Representative Preferred	16.0-31.1	34.8	10.0	8.0	6.8	6.5	6.2	5.7
Representative Preferred	14.0-16.0	18.8	7.0	6.7	6.5	6.3	6.1	5.1
Representative Preferred	12.0-14.0	17.4	6.7	6.5	6.4	6.2	6.0	4.9
Representative Preferred	10.0-12.0	7.9	6.6	6.4	6.2	5.9	5.5	4.1
Representative Preferred	4.5-10.0	7.2	6.4	6.3	5.9	5.3	5.0	2.1

Table TA 3-22
Annual Flow Volume at Imperial Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	33.5	8.1	5.8	5.6	5.5	5.5	5.2
CCS Comparative Baseline	14.0-16.0	19.1	5.7	5.6	5.5	5.4	5.3	4.8
CCS Comparative Baseline	12.0-14.0	17.3	5.6	5.6	5.5	5.3	5.3	4.0
CCS Comparative Baseline	10.0-12.0	9.2	5.6	5.5	5.3	5.2	4.6	2.8
CCS Comparative Baseline	4.5-10.0	5.8	5.5	5.3	5.2	4.3	3.6	1.3
No Action	16.0-31.1	33.1	7.8	5.8	5.7	5.6	5.5	5.1
No Action	14.0-16.0	18.7	5.7	5.7	5.6	5.5	5.5	5.0
No Action	12.0-14.0	18.2	5.7	5.6	5.6	5.5	5.3	3.7
No Action	10.0-12.0	9.2	5.6	5.6	5.5	5.0	4.4	2.4
No Action	4.5-10.0	5.8	5.6	5.5	5.0	4.1	3.5	1.5

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Basic Coordination	16.0-31.1	33.2	8.9	6.1	5.7	5.5	5.4	5.3
Basic Coordination	14.0-16.0	17.2	5.7	5.7	5.5	5.4	5.4	5.1
Basic Coordination	12.0-14.0	17.6	5.7	5.5	5.4	5.4	5.3	4.5
Basic Coordination	10.0-12.0	8.8	5.6	5.5	5.4	5.3	4.9	2.5
Basic Coordination	4.5-10.0	5.7	5.5	5.4	5.3	4.6	3.7	1.3
Enhanced Coordination	16.0-31.1	33.5	10.2	6.6	5.6	5.3	5.1	4.3
Enhanced Coordination	14.0-16.0	18.7	6.0	5.5	5.3	4.7	4.5	3.8
Enhanced Coordination	12.0-14.0	19.6	5.5	5.3	4.6	4.3	4.0	3.7
Enhanced Coordination	10.0-12.0	10.6	4.9	4.6	4.1	3.8	3.8	2.7
Enhanced Coordination	4.5-10.0	5.7	4.5	4.1	3.8	3.7	3.4	1.7
Max. Operational Flexibility	16.0-31.1	33.7	10.5	6.7	5.7	5.5	5.2	4.9
Max. Operational Flexibility	14.0-16.0	19.2	6.5	5.7	5.5	5.2	5.1	4.9
Max. Operational Flexibility	12.0-14.0	20.4	5.6	5.5	5.3	5.1	5.0	4.5
Max. Operational Flexibility	10.0-12.0	13.2	5.4	5.3	5.1	4.9	4.6	3.3
Max. Operational Flexibility	4.5-10.0	5.6	5.3	5.1	4.7	4.3	4.0	2.0
Supply Driven (LB Priority)	16.0-31.1	33.5	9.4	7.2	6.1	5.4	5.2	4.9
Supply Driven (LB Priority)	14.0-16.0	16.0	6.0	5.8	5.5	5.2	5.1	4.9
Supply Driven (LB Priority)	12.0-14.0	13.3	5.8	5.5	5.4	5.2	5.0	4.8
Supply Driven (LB Priority)	10.0-12.0	7.0	5.5	5.4	5.2	5.1	5.0	4.0
Supply Driven (LB Priority)	4.5-10.0	5.9	5.5	5.3	5.1	5.0	4.3	2.1
Supply Driven (LB Pro Rata)	16.0-31.1	33.5	9.5	7.2	6.3	5.0	4.8	4.5
Supply Driven (LB Pro Rata)	14.0-16.0	16.0	6.0	5.7	5.1	4.9	4.6	4.5
Supply Driven (LB Pro Rata)	12.0-14.0	14.5	5.7	5.4	4.9	4.7	4.5	4.3
Supply Driven (LB Pro Rata)	10.0-12.0	7.7	5.4	4.9	4.7	4.5	4.5	3.6
Supply Driven (LB Pro Rata)	4.5-10.0	5.9	4.9	4.9	4.6	4.5	4.1	2.2
Representative Preferred	16.0-31.1	33.5	9.0	6.9	5.7	5.4	5.3	4.8
Representative Preferred	14.0-16.0	17.4	5.9	5.7	5.4	5.3	5.2	4.2
Representative Preferred	12.0-14.0	15.9	5.7	5.4	5.3	5.3	5.1	4.0
Representative Preferred	10.0-12.0	6.5	5.5	5.4	5.3	5.0	4.5	3.3
Representative Preferred	4.5-10.0	5.9	5.4	5.3	5.0	4.2	4.1	1.4

Table TA 3-23
Annual Flow Volume Below Imperial Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	28.7	3.5	1.3	1.2	1.1	1.0	0.8
CCS Comparative Baseline	14.0-16.0	14.3	1.2	1.2	1.1	1.0	0.9	0.7
CCS Comparative Baseline	12.0-14.0	12.6	1.2	1.1	1.0	0.9	0.8	0.6
CCS Comparative Baseline	10.0-12.0	4.6	1.1	1.0	0.9	0.8	0.7	0.5
CCS Comparative Baseline	4.5-10.0	1.2	1.0	1.0	0.8	0.7	0.6	0.4

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
No Action	16.0-31.1	28.2	3.1	1.3	1.2	1.1	1.1	1.0
No Action	14.0-16.0	13.9	1.2	1.2	1.1	1.1	1.1	0.9
No Action	12.0-14.0	13.5	1.2	1.1	1.1	1.1	1.0	0.7
No Action	10.0-12.0	4.6	1.2	1.1	1.1	0.9	0.8	0.6
No Action	4.5-10.0	1.4	1.2	1.1	0.9	0.8	0.7	0.4
Basic Coordination	16.0-31.1	28.4	4.1	1.4	1.2	1.0	1.0	0.9
Basic Coordination	14.0-16.0	12.4	1.2	1.2	1.0	1.0	1.0	0.9
Basic Coordination	12.0-14.0	12.8	1.2	1.0	1.0	1.0	0.9	0.8
Basic Coordination	10.0-12.0	4.2	1.1	1.0	1.0	0.9	0.9	0.6
Basic Coordination	4.5-10.0	1.3	1.0	1.0	1.0	0.8	0.7	0.5
Enhanced Coordination	16.0-31.1	28.7	5.4	1.7	1.1	0.9	0.9	0.9
Enhanced Coordination	14.0-16.0	13.9	1.5	1.1	1.0	0.9	0.9	0.8
Enhanced Coordination	12.0-14.0	14.9	1.0	1.0	0.9	0.9	0.8	0.8
Enhanced Coordination	10.0-12.0	6.1	1.0	1.0	0.9	0.8	0.8	0.6
Enhanced Coordination	4.5-10.0	1.4	1.1	1.0	0.8	0.8	0.7	0.4
Max. Operational Flexibility	16.0-31.1	28.9	5.8	2.0	1.2	1.0	0.9	0.8
Max. Operational Flexibility	14.0-16.0	14.4	1.8	1.2	1.0	0.9	0.9	0.7
Max. Operational Flexibility	12.0-14.0	15.6	1.1	1.0	0.9	0.9	0.8	0.7
Max. Operational Flexibility	10.0-12.0	8.7	1.0	1.0	0.9	0.8	0.7	0.7
Max. Operational Flexibility	4.5-10.0	1.2	0.9	0.9	0.8	0.7	0.7	0.5
Supply Driven (LB Priority)	16.0-31.1	28.6	4.7	2.6	1.5	1.0	1.0	0.8
Supply Driven (LB Priority)	14.0-16.0	11.2	1.4	1.3	1.0	1.0	1.0	0.8
Supply Driven (LB Priority)	12.0-14.0	8.5	1.3	1.0	1.0	1.0	0.9	0.7
Supply Driven (LB Priority)	10.0-12.0	2.7	1.1	1.0	1.0	0.9	0.8	0.7
Supply Driven (LB Priority)	4.5-10.0	1.3	1.0	1.0	0.9	0.8	0.8	0.5
Supply Driven (LB Pro Rata)	16.0-31.1	28.6	4.9	2.6	1.6	1.1	1.1	0.9
Supply Driven (LB Pro Rata)	14.0-16.0	11.2	1.5	1.3	1.1	1.1	1.0	0.7
Supply Driven (LB Pro Rata)	12.0-14.0	9.8	1.3	1.1	1.1	1.0	1.0	0.7
Supply Driven (LB Pro Rata)	10.0-12.0	3.3	1.2	1.1	1.1	1.0	1.0	0.8
Supply Driven (LB Pro Rata)	4.5-10.0	1.4	1.1	1.1	1.0	1.0	0.8	0.5
Representative Preferred	16.0-31.1	28.6	4.4	2.3	1.2	0.9	0.9	0.7
Representative Preferred	14.0-16.0	12.6	1.2	1.2	0.9	0.9	0.9	0.7
Representative Preferred	12.0-14.0	11.4	1.2	0.9	0.9	0.9	0.9	0.7
Representative Preferred	10.0-12.0	2.2	0.9	0.9	0.9	0.8	0.7	0.6
Representative Preferred	4.5-10.0	1.3	1.0	0.9	0.9	0.7	0.7	0.4

Table TA 3-24
Annual Flow Volume Below Morelos Diversion Dam (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	16.0-31.1	27.4	2.2	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14.0-16.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12.0-14.0	11.3	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10.0-12.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	4.5-10.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
No Action	16.0-31.1	26.9	1.7	0.0	0.0	0.0	0.0	0.0
No Action	14.0-16.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12.0-14.0	12.2	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10.0-12.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0
No Action	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	16.0-31.1	27.1	2.8	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14.0-16.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12.0-14.0	11.5	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10.0-12.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	16.0-31.1	27.4	4.1	0.5	0.0	0.0	0.0	0.0
Enhanced Coordination	14.0-16.0	12.6	0.3	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12.0-14.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	10.0-12.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	-0.1
Max. Operational Flexibility	16.0-31.1	27.5	4.4	0.7	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14.0-16.0	13.0	0.5	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12.0-14.0	14.2	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10.0-12.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	16.0-31.1	27.3	3.4	1.3	0.2	0.0	0.0	0.0
Supply Driven (LB Priority)	14.0-16.0	9.8	0.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12.0-14.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10.0-12.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	16.0-31.1	27.3	3.5	1.4	0.3	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14.0-16.0	9.8	0.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12.0-14.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10.0-12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	16.0-31.1	27.3	3.1	1.1	0.0	0.0	0.0	0.0
Representative Preferred	14.0-16.0	11.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12.0-14.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10.0-12.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	4.5-10.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0

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Technical Appendix 4

Water Deliveries

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
1944 Water Treaty	1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2007 ROD	2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Record of Decision
2024 Final SEIS	Record of Decision
2024 ROD	2024 Near-term Colorado River Operations Record of Decision
ADM	Alternative Distribution Model
af	acre-feet
afy	acre-feet per year
Basin	Colorado River Basin
BCPA	Boulder Canyon Project Act
CCS	Continued Current Strategies
CRSS	Colorado River Simulation System
DCP	Drought Contingency Plan
DMDU	Decision Making under Deep Uncertainty
EIS	Environmental Impact Statement
IBWC	International Boundary and Water Commission
ICS	Intentionally Created Surplus
kaf	thousand acre-feet
kafy	thousand acre-feet per year
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
maf	million acre-feet
Mexico	United Mexican States
PPR	Present Perfected Right

Reclamation	Bureau of Reclamation
SAM	Shortage Allocation Model
Secretary	Secretary of the Interior
SNWA	Southern Nevada Water Authority
U.S.	United States
Upper Basin	Upper Colorado River Basin

TA 4. Water Deliveries

TA 4.1 Affected Environment

Water from the Colorado River is delivered to entities in the Lower Division States and the United Mexican States (Mexico) for domestic and agricultural use, in accordance with the Law of the River. Colorado River water is also used to serve many purposes in the Upper Colorado River Basin (Upper Basin). The geographic scope of this Environmental Impact Statement (EIS) does not extend above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users. With respect to Upper Basin conservation, the nexus to the proposed federal action is the storage and delivery of that conserved water in Lake Powell. The effects of this storage in and delivery from Lake Powell are within the scope of the EIS (see EIS **Chapter 3**, **Section 3.3**, Hydrologic Resources, and **TA 3**, Hydrologic Resources), while specific activities that may be undertaken in the Upper Basin to generate the conserved water are not within the scope of this EIS. Any such activities are unknown at this time and will not necessarily require federal decision making. Any federal decisions associated with these conservation activities will be assessed outside of this EIS.

The Law of the River is an umbrella term for the collection of laws, compacts, decrees, court decisions, contracts, and regulatory guidelines that govern management and operation of the Colorado River. Most notable among these documents are the Colorado River Compact of 1922, the Boulder Canyon Project Act (BCPA), the 1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty), the 1968 Colorado River Basin Project Act, and the 2006 Consolidated Decree (Reclamation 2016a). Several additions to this collection of documents include the: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 Final EIS; Reclamation 2007a) and Record of Decision (2007 ROD; Reclamation 2007b), which established the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines); Minute 323, Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin in 2017 (International Boundary and Water Commission 2017); the 2019 Lower Basin Drought Contingency Plan (DCP; Reclamation 2019), the 2024 Glen Canyon Long-Term Experimental and Management Plan Final Supplemental EIS (Reclamation 2016a) and Record of Decision (Reclamation 2016b); and the 2024 Near-term Colorado River Operations Final Supplemental EIS (Reclamation 2024a) and Record of Decision (2024 ROD, Reclamation 2024b). Specific to the Upper Basin, changes include implementation of the 2019 Upper Basin DCP's Drought Response Operating Agreement, which seeks to prevent reaching critically low elevations in Lake Powell while maintaining compliance with the Colorado River Compact. The 2007 Interim Guidelines and 2019 DCP are set to expire at the end of 2026, necessitating the development of new guidelines that are proposed and analyzed in this EIS.

The Colorado River Compact apportions 7.5 million acre-feet (maf) of water per year to the Upper Basin, and 7.5 maf to the Lower Colorado River Basin (Lower Basin), with division of the two basins occurring at Lees Ferry, Arizona. Within each basin, further apportionments are made to individual states and entities. The 2007 Interim Guidelines as modified by the 2024 ROD provide, among other things, guidelines for Normal, Surplus, and Shortage Conditions in the Lower Basin during the interim period through 2026.

This section describes historic water deliveries to entities within the Colorado River Basin (Basin), including apportionments to the Upper and Lower Division States, entitlements, depletion schedules, allotments to Mexico, and distribution of shortages to the Lower Division States. See EIS **Chapter 1**, **Section 1.8** for a description of historical water use across the Upper and Lower Basins.

TA 4.1.1 Apportionments to the Upper Division States

Water is distributed among the Upper Division States by the 1948 Upper Colorado River Basin Compact as a percentage of the total amount available for consumptive use each year after the deduction of Arizona's 50 thousand acre-feet (kaf) apportionment of Upper Basin water. These apportionment percentages are provided in **Table TA 4-1**. The Upper Division State apportionments have not yet been fully developed.

Table TA 4-1
Upper Division States Apportionment

State	Annual Apportionment (Percent)
Colorado	51.75
New Mexico	11.25
Utah	23.00
Wyoming	14.00

Source: Upper Colorado River Basin Compact 1948

TA 4.1.2 Apportionments to the Lower Division States

Water apportionments to the Lower Division States were established by the BCPA and are summarized in **Table TA 4-2**.

Table TA 4-2
Lower Division States Apportionment

State	Annual Apportionment (maf)
Arizona	2.8
California	4.4
Nevada	0.3
Total	**7.5**

Source: U.S. Congress 1928

TA 4.1.3 Water Delivery Entitlements to Entities in the Lower Division States

Rights to use Colorado River water within the Lower Division States, known as entitlements, are established in accordance with the BCPA and the Consolidated Decree. All of the water apportioned to the Lower Division States is allocated in accordance with these documents. For users in the Lower Division States, entitlements arise through (i) a decreed right, (ii) a Section 5 water delivery contract, or (iii) a Secretarial reservation.

According to Section 5 of the BCPA, the Secretary of the Interior (Secretary) is authorized as the contracting authority for the Lower Colorado River, and any user of Colorado River water in the Lower Basin is required to have a contract with the Secretary acting through the Bureau of Reclamation (Reclamation).

The Consolidated Decree lists and quantifies all Present Perfected Rights (PPRs) in the Lower Division States. PPRs are the highest priority Lower Basin mainstream Colorado River water entitlements that were perfected before June 25, 1929. The Consolidated Decree also lists federal reserved water rights for five Indian reservations. PPRs are satisfied first in order of priority in years when less than 7.5 maf of water is available from the Colorado River for consumptive use in the Lower Division States before other entitlements are fulfilled. A summary of the total amounts of water apportioned through PPRs for each of the Lower Division States is provided in **Table TA 4-3**. These entitlements are summarized in terms of both diversion and consumptive use. The return flows used to compute the consumptive use equivalent of diversion entitlements have been estimated from historical data.

Table TA 4-3
PPRs in the Lower Division States

State	Estimated Diversion Entitlement (acre-feet per year (afy))	Estimated Consumptive Use Entitlement (afy)
Arizona	1,077,971	597,811
California	3,019,573	2,801,326
Nevada	13,034	8,698
Total Lower Division States	**4,110,578**	**3,407,835**

Source: Reclamation 2023

The BCPA stipulates that all mainstream Colorado River water delivery contracts in the Lower Basin are for permanent use. Water delivery contracts may describe entitlements as an annual diversion, an annual consumptive use, or both.

A Secretarial reservation is an entitlement established by the Secretary for use at federal facilities or on federal lands. Secretarial reservations have been established for water use on Bureau of Land Management lands, on the Cibola, Imperial, and Havasu National Wildlife Refuges, at Hoover and Davis Dams, and at the Lake Mead National Recreation Area.

Storage & Delivery of Conserved and Non-System Water and Treatment of Pre-2027 Intentionally Created Surplus

As outlined in the 2007 Interim Guidelines, Lower Basin entitlement holders can store conserved water in Lake Mead, provided they have an Intentionally Created Surplus (ICS) exhibit and an approved ICS creation plan. ICS may only be created in a given year via approved conservation actions and a reduction in consumptive use. The ICS created is also subject to constraints as defined in the 2007 ROD (Reclamation 2007b) and the 2019 DCP agreement (Reclamation 2019).

Under the 2007 Interim Guidelines, ICS can be delivered to the Lower Division States when an ICS Surplus Condition is determined. The ICS Surplus Condition is enacted when (i) Lake Mead's January 1 elevation is projected to be above 1,075 feet, (ii) a Flood Control Surplus has not been determined, and (iii) delivery of ICS has been requested by one or multiple of the Lower Division States. The ICS Surplus Condition is enacted concurrent with the Normal operating condition in a given year and differs from other surplus conditions under the 2007 Interim Guidelines as discussed below. The Lower Basin DCP modified ICS delivery provisions, allowing for delivery of ICS below elevation 1,075 feet to elevation 1,025 feet. Beginning in 2027, guidelines regarding the delivery and creation of ICS will change in accordance with the 2007 ROD and Lower Basin DCP to incorporate additional thresholds and repayment timelines.

TA 4.1.4 Lower Division States' Water Supply Determination

As outlined in the Consolidated Decree and Article III of the 1968 Long-Range Operating Criteria, the Secretary determines the water supply condition for the Lower Division on an annual basis. The water supply conditions are:

- Normal Condition: sufficient water is available to satisfy 7.5 maf of consumptive use in the Lower Division States;
- Surplus Condition: sufficient water is available to satisfy an excess of 7.5 maf of consumptive use in the Lower Division States; and
- Shortage Condition: insufficient water is available to satisfy 7.5 maf of consumptive use in the Lower Division States.

The 2007 ROD provides objective criteria used to make annual water supply determinations. The supply condition is annually determined based on the projected elevation of Lake Mead on January 1, as modeled by the prior year's August 24-Month Study (Reclamation 2024c). The guidance provides supply thresholds under which the consumptive use from Lake Mead would be Normal, Surplus, or Shortage Conditions, as well as outlining coordinated reservoir management strategies between Lake Powell and Lake Mead.

Under a Surplus Condition, 46 percent of the surplus water is to be apportioned to Arizona, 50 percent to California, and 4 percent to Nevada, as outlined in the Consolidated Decree. In addition to the Consolidated Decree, the 2007 Interim Guidelines provide guidance regarding when a Surplus Condition should be declared, how surplus water should be distributed by use (e.g., agriculture, domestic, etc.), and recognition of modifications to surplus distributions amongst the states via forbearance agreements. Lake Mead has not operated in a Surplus Condition since the publication of the 2007 ROD.

Table TA 4-4 summarizes historical ICS deliveries for the Lower Division States. Note that states may elect not to request ICS deliveries during an ICS Surplus year, and may also create ICS during that year, hence some of the years under this condition display zero volume delivered.

Table TA 4-4
Lower Basin Annual Historical ICS Deliveries by State

Calendar Year	Operating Condition	ICS Delivered (acre-feet (af))			
		AZ	CA	NV	Total
2008	Normal/ICS Surplus	0	46,976	9,638	56,614
2009	Normal/ICS Surplus	0	0	0	0
2010	Normal/ICS Surplus	0	5,191	0	5,191
2011	Normal/ICS Surplus	0	0	0	0
2012	Normal/ICS Surplus	0	0	1,000	1,000
2013	Normal/ICS Surplus	0	93,857	0	93,857
2014	Normal/ICS Surplus	0	320,992	0	320,992
2015	Normal/ICS Surplus	0	70,756	75,000	145,756
2016	Normal/ICS Surplus	0	0	0	0
2017	Normal/ICS Surplus	0	0	0	0
2018	Normal/ICS Surplus	0	0	0	0
2019	Normal/ICS Surplus	0	0	0	0
2020	Normal/ICS Surplus and DCP Contributions	4,606	0	0	4,606
2021	Normal/ICS Surplus and DCP Contributions	0	18,786	0	18,786
2022	Level 1 Shortage and DCP Contributions	52,841	111,392	0	164,233
2023	Level 2 Shortage and DCP Contributions	1,318	0	0	1,318
2024	Level 1 Shortage and DCP Contributions	8,180	0	0	8,180
2025	Level 1 Shortage and DCP Contributions	0	0	0	0

Source: Reclamation 2024d

Under a Shortage Condition, the Consolidated Decree stipulates that all PPRs must be satisfied first in order of their priority dates before the remaining available water can be allocated consistent with the BCPA and other applicable federal statutes. In total, the annual water supply condition is currently governed by Section 2 of the 2007 Interim Guidelines, Articles III(3)(c) of the Operating Criteria and Article II(B)(3) of the Consolidated Decree, the 2019 Lower Basin DCP, and the 2024 ROD.

Each year, Reclamation develops an Annual Operating Plan for management of reservoirs on the Colorado River. The Annual Operating Plan reports on rules, guidelines, and decisions made for operations in the previous year as well as projected operations for the upcoming year. From 2008 to 2021, Lake Mead operated in an ICS/Surplus Condition, before switching to a Shortage Condition

for the years 2022 through 2025. Additionally, DCP contributions were implemented from 2020 through 2025 (Reclamation 2024d).

TA 4.1.5 Depletion Schedules for Upper Division States

Projected depletions for the Upper Division States were updated in 2017 and adopted in 2022 by the Upper Colorado River Commission. This includes detailed depletion volumes on a decadal basis through 2070 for each of the Upper Division States. Tabular data for these projections through 2060[1] can be found in **Appendix L**, Upper Division States Depletion Schedules**.**

TA 4.1.6 Depletion Schedules for the Lower Division States

Projected mainstream depletions for the Lower Division States can be found in **Appendix M**, Lower Division States Depletion Schedules.

Historical lower Colorado River mainstream consumptive use by state is shown from 2008 to 2025 in **Table TA 4-5**. At the time of this report, the data was only available through 2025. Total annual lower Colorado River mainstream consumptive use has declined on average from 2008 to 2025.

Table TA 4-5
Consumptive Use of Lower Colorado River Mainstream Water by Lower Division States (Annual)

Calendar Year	Arizona (af)	California (af)	Nevada (af)	Lower Division States Total (af)
2008	2,752,497	4,498,810	269,654	7,520,961
2009	2,831,711	4,358,074	248,613	7,438,398
2010	2,780,367	4,356,839	241,437	7,378,643
2011	2,781,108	4,312,661	222,847	7,316,616
2012	2,789,667	4,416,718	237,161	7,443,546
2013	2,778,867	4,475,789	223,563	7,478,219
2014	2,774,661	4,649,734	224,616	7,649,011
2015	2,604,732	4,620,756	222,729	7,448,217
2016	2,612,833	4,381,101	238,326	7,232,260
2017	2,509,503	4,026,515	243,425	6,779,443
2018	2,632,260	4,265,525	244,103	7,141,888
2019	2,491,707	3,840,686	233,996	6,566,389
2020	2,470,776	4,059,911	255,568	6,786,255
2021	2,425,736	4,404,727	242,168	7,072,631
2022	2,014,176	4,424,247	223,670	6,662,093
2023	1,889,517	3,699,155	186,844	5,775,516
2024	1,934,518	3,943,741	212,428	6,090,687
2025	1,910,524	3,646,992	197,570	5,755,086

Source: Reclamation 2026

[1] While the UCRC depletion demand schedule is through 2070, the CRSS modeling was only performed through 2060.

TA 4.1.7 Mexico's Allotment

Mexico's allotment of Colorado River water is described under Article 10 of the 1944 Water Treaty. The 1944 Water Treaty guarantees that 1.5 maf will be delivered to Mexico annually. Additionally, it outlines Surplus Conditions such that no greater than 1.7 maf shall be delivered to Mexico in a given year, and Extraordinary Drought such that deliveries are reduced in proportion to reductions of United States (U.S.) consumptive uses. Minute 242 provides guidance for the geographic locations where deliveries from the U.S. will be made, specifically that approximately 1.36 maf will be delivered upstream of Morelos Diversion Dam, with the remainder being delivered downstream of the dam. Subsequent agreements included Minute 319 to the 1944 Water Treaty, which established four coordination mechanisms that affected flows in the International Border Region of the Colorado River. Upon Minute 319's expiration, Minute 323 built upon and extended these provisions by providing operational flexibility, storage options, and binational mechanisms for adjusting deliveries to Mexico under low and high elevation reservoir conditions.

Minute 323 does not change Mexico's allotment, but it does adjust how and under what conditions deliveries occur. Since 2019, the deliveries to Mexico were further adjusted for water savings contributions, as required under Minute 323, and since 2021 for reductions under low elevation reservoir conditions. Minute 323 additionally secures Mexico's ability to create water for or take delivery of Mexico's Water Reserve. Mexico's Water Reserve refers to the volume of Mexico's Colorado River allotment that is intentionally deferred (not taken for immediate use) and stored in Lake Mead for later delivery or recovery. This is in addition to the volumes of Mexico's Recoverable Water Savings, which are deferred during certain low reservoir elevations for recovery at a future time. Deliveries to Mexico were further adjusted in 2024, 2025, and 2026 through additional conserved water by Mexico under Minute 330.

Modeling assumptions have been made to project deliveries to Mexico. These projected deliveries are for analysis purposes only and are not intended to reflect an interpretation or application of the 1944 Water Treaty or to be misconstrued as U.S. policy regarding water deliveries to Mexico. For further information regarding Mexico's allotment and pertinent policy, please refer to **Appendix N**, International Border Region of the Colorado River.

TA 4.1.8 Distribution of Shortages and Reductions to and within the Lower Division States

The 2007 Interim Guidelines, the 2019 DCP and Minute 323 to the 1944 Water Treaty provide for a maximum of 1.375 maf of shortages and reductions (including DCP contributions and BWSCP savings). Beyond these required activities, Reservoir Protection Conservation implemented through the 2024 ROD resulted in additional Lower Basin conservation from 2023 to 2026. The Reservoir Protection Conservation may vary year to year, but is designed to achieve a collective total volume of 3.0 maf. A summary of the 2007 Interim Guidelines Shortages, 2019 DCP contributions, and 2024 ROD conservation is shown in **Table TA 4-6**.

Distribution of Shortages within Arizona

Arizona's 2.8 maf apportionment is allocated via the priority system outlined in **Table TA 4-7**, as presented and analyzed in the 2007 Final EIS. Arizona's priority system is divided into six priorities as displayed in **Table TA 4-7**.

Table TA 4-6
Lower Division States' Total 2007 ROD Shortages, 2019 DCP Contributions, and 2024 ROD Conservation

Lake Mead Elevation (feet)	2007 ROD Shortages + 2019 DCP Contributions (kaf)				2024 ROD Conservation (kaf)*				Total 2007 ROD Shortages + 2019 DCP Contributions + 2024 ROD Conservation (kaf)**			
	AZ	NV	CA	Total	AZ	NV	CA	Total	AZ	NV	CA	Total
1,090 – 1,075	192	8	0	200	280	70	400	750	472	78	400	950
1,075 – 1,050	512	21	0	533					792	91	400	1,283
1,050 – 1,045	592	25	0	617					872	95	400	1,367
1,045 – 1,040	640	27	200	867					920	97	600	1,617
1,040 – 1,035	640	27	250	917					920	97	650	1,667
1,035 – 1,030	640	27	300	967					920	97	700	1,717
1,030 – 1,025	640	27	350	1,017					920	97	750	1,767
<1,025	720	30	350	1,100					1,000	100	750	1,850

Source: Reclamation 2024a
* Actual 2024 ROD conservation by state may vary each year depending on the conservation agreements in place in that year. 2024 ROD conservation shown are approximations and only apply for years 2023 to 2026, such that collectively a total of 3.0 maf of 2024 ROD conservation would occur through 2026.
** The total of 2007 ROD shortages, DCP contributions, 2024 ROD conservation, and any other additional conservation would not exceed 2.083 maf in a given year. These total volumes only apply to 2023 through 2026.

Table TA 4-7
Arizona's Priority System for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	PPRs established prior to June 25, 1929
Second[1]	Federal reservations and perfected rights established or effective prior to September 30, 1968
Third[1]	Entitlements pursuant to contracts executed on or before September 30, 1968
Fourth	(1) Entitlements pursuant to contracts, Secretarial reservations, and other arrangements between the U.S. and water users established subsequent to September 30, 1968 (2) Contract for Central Arizona Project
Fifth	Any unused Arizona entitlement
Sixth	Entitlements to surplus water

Source: Reclamation 2024a
[1] The Arizona second and third priorities are coequal in their priority.

Distribution of Shortages within California

California's 4.4 maf apportionment is allocated using a priority system based upon Secretarial regulations which incorporate provisions of the California Seven-Party Agreement of 1931. California's priority system is outlined below in **Table TA 4-8** from the 2007 Final EIS.

Table TA 4-8
California Seven-Party Agreement Priorities for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	PPRs established prior to June 25, 1929: Palo Verde Irrigation District for beneficial use upon 104,500 acres
Second	Reclamation's Yuma Project for beneficial use on up to 25,000 acres
Third[1,2]	(a) Imperial Irrigation District and Coachella Valley Water District (b) Palo Verde Irrigation District for use on 16,000 acres on the Lower Palo Verde Mesa
Fourth[3]	Metropolitan Water District and/or the City of Los Angeles and/or others on the coastal plain of Southern California for 550 thousand acre-feet per year (kafy)
Fifth	(a) Metropolitan Water District and/or the City of Los Angeles and/or others on the coastal plain of Southern California for 550 kafy (b) City and/or County of San Diego for 112 kafy
Sixth[4]	(a) Imperial Irrigation District and Coachella Valley Water District (b) Palo Verde Irrigation District for use on Lower Palo Verde Mesa
Seventh	All remaining water available within California for agricultural use

Source: Reclamation 2024a

[1] The total beneficial use of priorities 1, 2, and 3 shall not exceed 3.85 mafy.

[2] Article 4.7 of the Quantification Settlement Agreement by and among Imperial Irrigation District, The Metropolitan Water District of Southern California, and Coachella Valley Water District, dated October 10, 2003, refers to provisions of the Acquisition Agreements and the Allocation Agreement regarding shortage sharing between these two agencies.

[3] The sum of priorities 1 through 4 is 4.4 mafy.

[4] The sum of priority 6 is 300,000 afy.

Distribution of Shortages within Nevada

Nevada's 0.3 maf apportionment is allocated as outlined in **Table TA 4-9** below. The priority system was designed and implemented in 1992 through the contracting of Southern Nevada Water Authority (SNWA) by Reclamation for the balance of Nevada's apportionment.

Table TA 4-9
Nevada's Priority System for Mainstream Colorado River Water

Priority	Rights to Be Satisfied
First	PPRs established prior to June 25, 1929: Fort Mojave Indian Reservation (12,534 afy) Lake Mead National Recreation Area (Diversion = 500 afy or Consumptive Use = 300 afy)
Second	Lake Mead National Recreation Area (1,500 afy, estimated)
Third	Boulder City (5,876 afy)
Fourth	City of Henderson (15,878 afy) Precision Castparts Corporation or Henderson Water Company, LLC (8,208 afy) SNWA (from Basic Water Company) (14,950 afy)
Fifth	Lakeview Company (0 afy) Pacific Coast Building Products (928 afy)
Sixth	Las Vegas Valley Water District (15,407 afy)

Priority	Rights to Be Satisfied
Seventh	U.S. Air Force (delivery from SNWA; 4,000 afy), Boy Scouts (annexed by SNWA; 10 afy), Reclamation (300 afy), and Nevada Department of Wildlife (formerly Nevada Department of Fish and Game; consumptive use 25 afy)
Eighth	Robert B. Griffith Project (308,000 afy) and Big Bend (10,000 afy) SNWA (balance of state apportionment, unused and surplus)

Source: Reclamation 2024a

TA 4.2 Environmental Consequences

This section compares water deliveries from the mainstream Colorado River under the No Action Alternative, four action alternatives (as described in **Appendix S**), the Continued Current Strategies (CCS) Comparative Baseline (as described in **Chapter 3**, **Section 3.2.4**), and the Representative Preferred Alternative (as described in **Chapter 2**).

As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative Preferred Alternative, which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval.

TA 4.2.1 Methodology

This section examines potential effects on water deliveries under the action alternatives as compared to the No Action Alternative and the CCS Comparative Baseline. Potential impacts are considered for the following water delivery resources: shortage volumes, dead pool–related reductions, depletion volumes, and surplus volumes. Also provided is a comparison of Upper Basin conservation across the alternatives.

Reclamation uses the Colorado River Simulation System (CRSS) model for long-term planning studies. CRSS simulates Basin conditions decades into the future (the full analysis period is through 2060) and can be used to account for hydrologic and operational uncertainty. CRSS is a monthly time-step model that produces reservoir elevations, releases, and river flows as outputs. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model documentation.

Additionally, the Shortage Allocation Model(s) (SAM) and Alternative Distribution Model(s) (ADM) were used to analyze potential impacts of the alternatives on individual water users within each Lower Division State under varying levels of shortage. Modeling assumptions for the SAMs and ADMs are summarized in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

Decision Making under Deep Uncertainty (DMDU) is the approach used for quantitative analysis. It is a non-probabilistic evaluation framework that compares alternatives based on their ability to meet

specific performance criteria in many potential future conditions and analyzes how the alternatives respond to specific hydrologic conditions. Additional background and technical details about the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach.

Throughout the analysis, there are three standard figures: conditional boxplots, robustness heatmaps, and vulnerability bar plots. Each type of figure explains key information regarding performance. When taken together, the figures provide a full picture of how the alternatives compare and whether significant negative impacts are reasonably foreseeable under each alternative. The conditional boxplot figures show how the alternatives respond to different categories of preceding hydrology and enable a comparison of alternatives in specific hydrologic conditions (e.g., average conditions or dry conditions). To create these figures, all 34 years (2027–2060) from all 400 simulated futures (13,600 data points per alternative) are separated into five categories based on their preceding 3-year average Lees Ferry natural flow. Robustness heatmaps show the alternatives' ability to meet different levels of performance over one or more decades in the wide range of potential future conditions used in the analysis. Vulnerability bar plots provide complementary analysis to the robustness heatmaps by identifying the specific hydrologic conditions in which each alternative is likely to succeed or fail the preferred minimum performance level. For more information about these figures and detailed interpretation guidance, see **Chapter 3**, **Section 3.2.6**, Decision Making under Deep Uncertainty.

Impact Analysis Area

The geographic scope of the water deliveries analysis is the Colorado River corridor from the upstream limit of full pool elevation of Lake Powell to the downstream limit of the Southerly International Boundary. The geographic scope of this EIS does not extend above Lake Powell and accordingly does not include an analysis of the impact on Upper Basin water users. Although assumptions about Upper Basin conservation are included in various alternatives, no assumptions are made with respect to where conserved water is generated nor about the specific activities that produce it (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water, for more information).

Assumptions

CRSS was used to analyze shortage volumes and Lower Basin water deliveries, and the SAMs and ADMs were used to analyze shortage impacts on specific groups of water users. CRSS also includes assumptions regarding Upper Basin conservation activities but does not make assumptions with respect to conservation by different entities or via specific activities. Refer to their respective appendices for more details related to model assumptions and documentation. All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (see **Chapter 2**, **Section 2.4;** see also **Appendix S**). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

Impact Indicators

This section discusses impacts on the Lower Division States' water deliveries, deliveries to Mexico, and the distribution of shortages within the Lower Division States. To quantify impacts, the following indicators are used:

- Magnitude of shortage volumes
- Distribution of shortages and depletions among and within the Lower Division States

TA 4.2.2 Issue 1: Apportionments to the Upper Division States

The alternatives would not affect apportionments to the Upper Division States. Therefore, no impact analysis is warranted.

TA 4.2.3 Issue 2: Lower Division States' Apportionments and Water Entitlements

The approaches to distributing shortages incorporated in all alternatives are designed to explore a wide range of potential concepts and impacts; they do not reflect an intention by Reclamation to alter apportionments or water entitlements. However, because the concepts would affect a range of users, impacts on deliveries to different entities are analyzed in Issues 3, 5, and 7, and addressed in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation.

TA 4.2.4 Issue 3: Lower Division States' Water Supply Determinations

Issue 3 addresses how operational activities affect water deliveries for the Lower Division States and Mexico. It also presents total Basin conservation activity across different alternatives. Impacts will be analyzed through the comparison of the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Annual Lower Basin Reductions (Shortage and Lake Mead Dead Pool–Related Reductions)
- Effects of Modeling Assumptions for Upper Basin and Lower Basin Conservation Activity on Lower Basin Shortages and Deliveries
- Shortage
- Maximum Shortage
- 2027 Shortage Volumes Under Each Set of Initial Conditions
- Annual Lower Basin Shortage
- Annual Shortage by State (Arizona, California, Nevada) and water delivery reductions to Mexico
- Annual Depletions by State (Arizona, California, Nevada) and Mexico
- Surplus

Shortage vs Dead Pool–Related Reductions: Comparison for full Lower Basin

Shortage refers to delivery reductions at the Basin, state, or individual apportionment level that are defined and distributed as part of an alternative's shortage operations. Volumes and distributions of shortage are described in **Chapter 2**. Dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. In some cases, these unplanned reductions

occur because Lake Mead is approaching dead pool (elevation 895 feet), and in some cases they occur higher (up to elevation 950 feet).

Note that the approach to distributing unplanned reductions associated with dead pool is not a component of any alternative. It is important for the impact analysis to show that these volumes occur, but it is not appropriate to analyze how they may impact specific states or users. Therefore, shortage results beyond this section will focus on shortage only. Where impacts due to dead pool–related reductions are presented, they will be specifically noted.

Annual Lower Basin Reductions

Figure TA 4-1 shows annual Lower Basin shortages and dead pool–related reductions for each alternative using conditional boxplots. The box plots show how the alternatives perform under varying hydrologic conditions, defined by the preceding three-year average of Lees Ferry natural flow. The bottom and top of each box capture the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and outliers are shown as dots. To enable easier comparison of all flow categories, the vertical axes have been truncated at the high end, and some outliers in the Critically Dry Flow Category have been omitted. Statistical summaries of the left and right columns are provided in **Table TA 4-10** and **Table TA 4-11** at the end of this technical appendix.

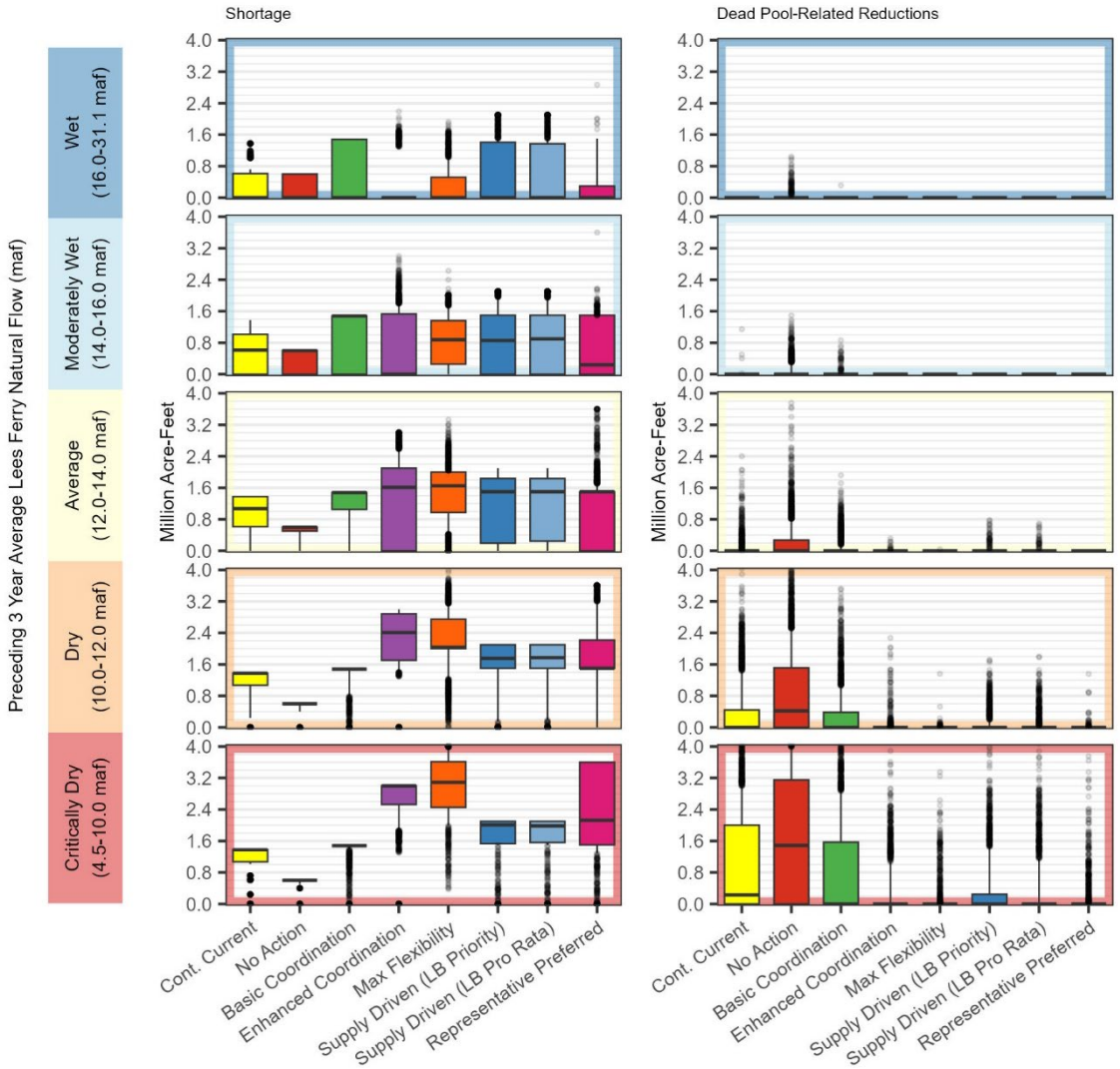
Generally, lower maximum volumes of shortages correspond to higher frequency and larger volumes of dead pool–related reductions, seen most prominently in the No Action Alternative. Dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. In the Average Flow Category, the medians and interquartile ranges for shortage involve reductions of 2.1 maf or less. The Maximum Operational Flexibility Alternative has the highest median shortage at 1.7 maf. The Enhanced Coordination Alternative has a median shortage of 1.6 maf and has the largest interquartile range of shortages. The remaining action alternatives have less variability (smaller interquartile ranges) but similar medians; all action alternative medians are higher than the CCS Comparative Baseline (1.1 maf) and the No Action Alternative (0.6 maf).

In the Average Flow Category, all action alternatives except for the Basic Coordination Alternative have infrequent dead pool–related reductions: only the outlier years, if any at all, and the largest volume is 0.8 maf. The Basic Coordination Alternative has greater maximum dead pool–related reductions of 1.9 maf, similar to the 2.4 maf for the CCS Comparative Baseline. The No Action Alternative has the most frequent and highest magnitude dead pool–related reductions, with a maximum value of 3.8 maf in the Average Flow Category.

The greatest contrast between alternatives occurs in the Critically Dry Flow Category. All action alternatives except for the Basic Coordination Alternative show increases in median shortage reductions compared to their respective medians in the Average Flow Category, with the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative reaching median shortages of 3.0 maf and 3.1 maf, respectively. The No Action Alternative has the lowest median shortage among all alternatives, and the Basic Coordination Alternative has the second lowest median shortage at 1.5 maf. These two alternatives have minimal variability because they are almost

always at their maximum shortages, but this leads to much larger medians and variability in dead pool-related reductions than other alternatives.

Figure TA 4-1
Annual Lower Basin Reductions



Note: Shortage and dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the International Boundary and Water Commission (IBWC) in consultation with the Department of State.

While dead pool–related reductions increase across all alternatives as the flow categories become drier, these reductions only occur above the 50th percentile (i.e., in less than 50 percent of years) for all action alternatives in the Critically Dry Flow Category. While shortages under the Basic Coordination Alternative remain low (not exceeding 1.5 maf), this alternative results in a larger percentage of futures with dead pool–related reductions from Lake Mead as it is compared to other

action alternatives. In the Critically Dry Flow Category, all action alternatives have lower dead pool–related reductions than the CCS Comparative Baseline and the No Action Alternative.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median shortage is 1.5 maf, and there is variability within the interquartile range, especially comparing the 75th percentile volume of 2.2 maf to the median. The median dead pool-related reduction is 0.0 maf, and only outlier years exhibit any dead pool-related reductions, with a maximum of 1.4 maf.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median shortage is 2.1 maf, and the interquartile range is large (25th and 75th percentile of 1.5 and 3.6 maf, respectively). The median dead pool-related reductions are 0.0 maf, and 10 percent of years exhibit dead pool-related reductions with a maximum of 3.8 maf. (Note that the 2027-2028 Operating Guidelines specify a maximum shortage of 1.5 maf, and consultations triggered by critical elevations at Lake Mead would be undertaken before larger volumes of shortage could occur during that term.)

Lake Mead Dead Pool-Related Reductions

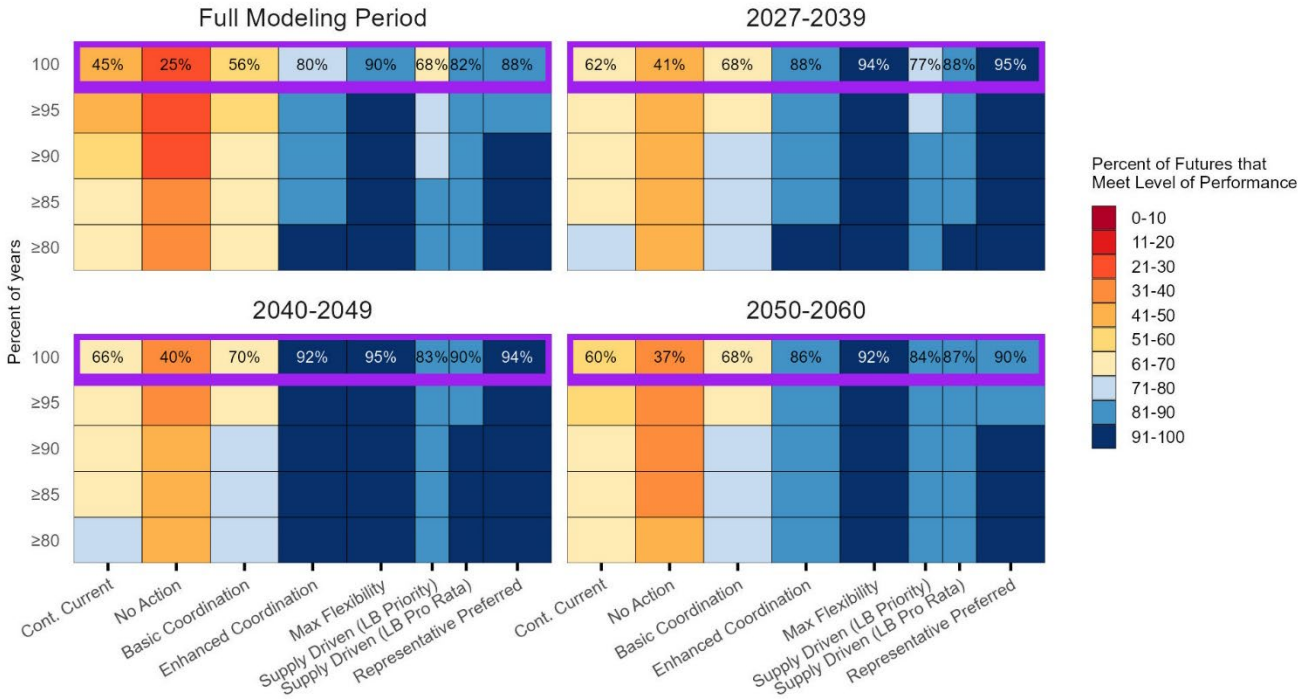
Lake Mead Dead Pool-Related Reductions Robustness

Figure TA 4-2 below depicts the ability of each alternative (columns) to avoid dead pool–related reductions at Lake Mead in the specified percent of years (rows). Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative avoids dead pool–related reductions in 100 percent of years.

Over the full modeling period, the Maximum Operational Flexibility Alternative is the most robust, avoiding any dead pool-related reductions in 90 percent of the futures, followed by the Representative Preferred Alternative and Supply Driven (Lower Basin Pro Rata [LB Pro Rata] approach) Alternatives, which avoid dead pool-related reductions in 88 and 82 percent of the futures, respectively. The Enhanced Coordination Alternative avoids dead pool-related reductions in 80 percent of modeled futures. All four of these action alternatives, as well as the Supply Driven Alternative (Lower Basin Priority [LB Priority] approach), are more robust than the Basic Coordination Alternative and the CCS Comparative Baseline, which avoid dead pool-related reductions in 56 percent and 45 percent of futures, respectively. The No Action Alternative is the least robust, avoiding dead pool-related reductions in only 25 percent of futures.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Representative Preferred and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance level in 95 and 94 percent of futures, respectively. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives both meet the preferred minimum performance level in 88 percent of futures, and the Supply Driven Alternative (LB Priority approach) meets this performance level in 77 percent of futures. The No Action and Basic Coordination Alternatives and the CCS Comparative Baseline are less robust, meeting the preferred minimum performance level in 41, 68, and 62 percent of futures, respectively.

Figure TA 4-2
Lake Mead Dead Pool-Related Reductions: Robustness
Percent of futures in which dead pool-related reductions are avoided in the percent of years specified by each row



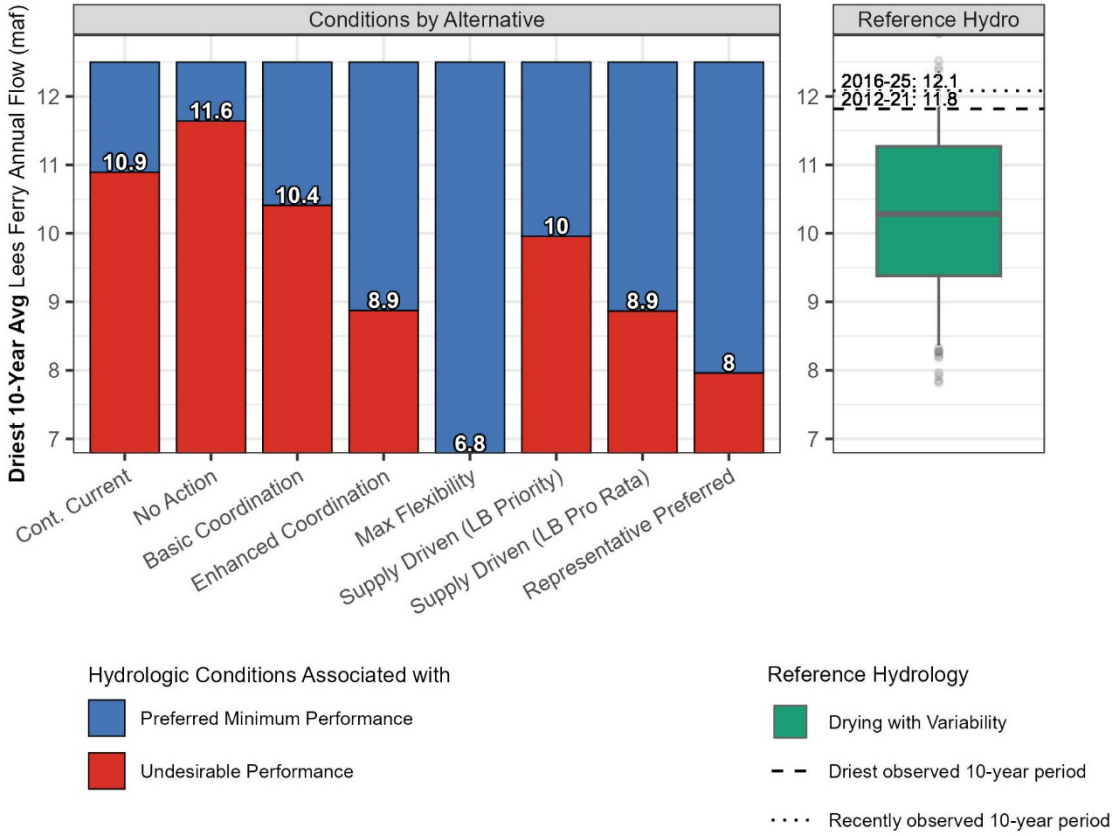
Note: Dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Lake Mead Dead Pool-Related Reductions Vulnerability

Figure TA 4-3 below shows what flow conditions are likely to cause dead pool–related reductions from Lake Mead in any year. This definition of undesirable performance is based on the highlighted row in **Figure TA 4-2** above, which defined a future as successful when an alternative avoided dead pool–related reductions 100 percent of the time.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the observed record and the Drying with Variability Ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

Figure TA 4-3
Lake Mead Dead Pool–Related Reductions: Vulnerability.
Conditions that could cause Lake Mead Dead Pool–Related Reductions in Any Year



Note: Dead pool-related reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The Basic Coordination Alternative would likely be vulnerable to dead pool-related reductions under a 10-year average Lees Ferry natural flow of 10.4 maf or drier, which is slightly less vulnerable than the CCS Comparative Baseline, which is likely to be vulnerable if the 10-year average is 10.9 maf or drier. The No Action Alternative is vulnerable to a 10-year average of 11.6 maf, which is similar to the driest observed 10-year average of 11.8 maf. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are not likely to be vulnerable to undesirable performance unless the 10-year average flow is much drier than any observed conditions, and fewer than 50 percent of the traces in the Drying with Variability ensemble include conditions that would be likely to cause vulnerability in these alternatives. Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of dead pool-related reductions under a 10-year average flow of 8.0 maf. This alternative is not likely to be vulnerable in the next 10 years because these conditions

have not been observed and they occur in fewer than 10 percent of traces in the Drying with Variability Ensemble, which represents how hydrologic conditions may change in a warmer future.

Conservation Activity

All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and Lake Mead. **Table TA 4-12** below summarizes the various conservation mechanisms for each action alternative. Refer to **Chapter 2** and **Appendix S** for specifics related to each alternative's policy on conservation.

For modeling purposes, assumptions about conservation and delivery of pre-2027 conserved water were developed to show the maximum impacts of the conservation pools on reservoir elevations and downstream flows; they are not intended to represent specific activities or constraints on individual users. See **Chapter 2** and **Appendix S** of the EIS for more information about the assumptions for each alternative. Upper Basin conservation activity is discussed in Issue 6, below.

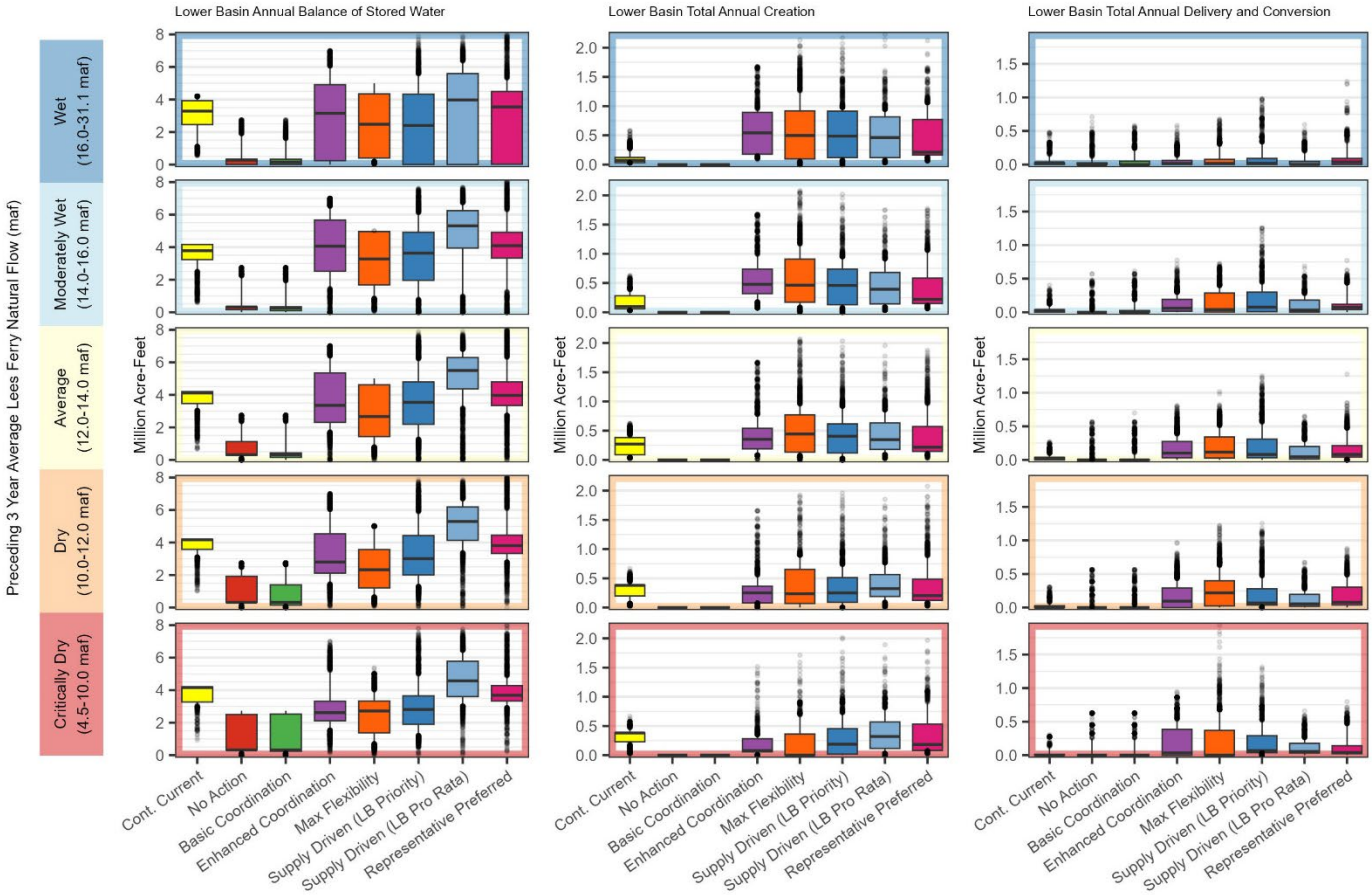
Table TA 4-12
Summary of Conservation Mechanisms by Alternative

Alternative	Conservation Pool Volume	Conservation Pool Mechanism
CCS Comparative Baseline	0.5 maf	Upper Basin pool in Lake Powell
	4.2 maf	Lower Basin pool in Lake Mead
No Action		No new mechanism; delivery of pre-2027 conservation only
Basic Coordination		No new mechanism; delivery of pre-2027 conservation only
Enhanced Coordination	2 maf	Upper Basin pool in Lake Powell
	5 maf	Lower Basin pool in Lake Mead
	2 maf	Protection Pool in Lake Mead
Maximum Operational Flexibility	5 maf	Upper Basin pool (distributed strategically across Lake Powell and Lake Mead)
	3 maf	Lower Basin pool (distributed strategically across Lake Powell and Lake Mead)
Supply Driven (both LB Priority and LB Pro Rata approaches)	3 maf	Upper Basin pool in Lake Powell
	8 maf	Lower Basin pool in Lake Mead
Representative Preferred	3 maf	Upper Basin pool in Lake Powell
	7 maf	Lower Basin pool in Lake Mead
	1 maf	Federally Managed Water Resources Pool in Lake Mead

Lower Basin Conservation Activity

Figure TA 4-4 shows three components of Lower Basin conservation activity for each alternative[2] using three columns of conditional boxplots. The first column shows the annual balance of stored water, which includes any conserved water retained in system reservoirs from prior years. The second column shows total annual creation, which represents new conservation generated each year. The third column shows total annual delivery and conversion, which represents the use of previously conserved water to meet authorized operational purposes. Statistical summaries of the data shown in **Figure TA 4-4** are provided in **Table TA 4-13** through **Table TA 4-15** at the end of this technical appendix.

Figure TA 4-4
Annual Lower Basin Conservation Activity



Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[2] For all alternatives except the Maximum Operational Flexibility Alternative, Lower Basin conserved water is only stored in Lake Mead. For the Maximum Operational Flexibility Alternative, this water can be stored in Lake Mead, Lake Powell, or both.

In the Average Flow Category, the Supply Driven (LB Pro Rata approach) Alternative has the highest median balance of stored water at 5.5 maf (left column). The Supply Driven Alternative (LB Priority approach) has the same size pool, but a lower median balance of 3.5 maf due to different assumptions about shortage distribution and conservation activity among Lower Basin water users. The CCS Comparative Baseline has a higher median balance than the Enhanced Coordination and Maximum Operational Flexibility Alternatives, but the ranges of the banks in those two action alternatives are larger because they have larger pools. The No Action and Basic Coordination Alternatives have small balances of stored water because they do not include new conservation mechanisms and the balances only reflect pre-2027 conservation. The Representative Preferred Alternative has a similar median to the CCS Comparative Baseline, 4.0 maf and 4.1 maf, respectively, but more variability due to a larger-sized bank.

In the Dry and Critically Dry Flow Categories, the relative rankings of median balances are similar to those in the Average Flow Category, but balances decrease because annual creation volumes (middle column) decrease as conditions get drier. Conversion and delivery volumes (right column) increase between the Average and Dry Flow Categories, but stay the same or decrease in the Critically Dry Flow Category due to lower available stored water and/or low Lake Mead elevations that preclude delivery or conversion.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median annual balance of stored water is 3.8 maf, and there is relatively low variability within the interquartile range: the 75th percentile balance is 4.5 maf, and the 25th percentile balance is 3.3 maf. The median volume of annual creation is 0.2 maf, and the median volume of annual delivery and conversion is 0.1 maf.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median annual balance of stored water is 3.7 maf, and there is relatively low variability within the interquartile range: the 75th percentile balance is 4.3 maf, and the 25th percentile balance is 3.3 maf. The median volume of annual creation is 0.2 maf, and the median volume of annual delivery and conversion is 0.0 maf.

Effects of Modeling Assumptions for Total Basin Conservation Activity on Lower Basin Shortages and Deliveries

The following section evaluates how modeling assumptions about conservation activities (which are different for each alternative) affect Lower Basin shortages and depletions by comparing scenarios with all conservation activities removed to those that include conservation activities. While the No Action and Basic Coordination Alternatives do not include mechanisms to conserve and store water in Lake Powell or Lake Mead, the alternatives do include assumptions for the delivery of existing ICS that was conserved prior to 2027. In the conservation-off results, activity related to pre-2027 conservation is turned off for all the alternatives and the CCS Comparative Baseline.

For the purposes of this technical appendix, the analysis for each figure comparing the effects of conservation activities will provide context for the subsequent figures; it will not synthesize the implications of different conservation mechanisms across resources.

Shortage

Figure TA 4-5 shows the effects of conservation activity on annual Lower Basin shortages using paired boxplots. For each alternative, conservation activity is turned on for the left of each pair (darker color) and conservation activity is turned off for the right of each pair (lighter color). Unless otherwise specified, all analyses in this EIS have conservation activity turned on. A statistical summary of the data shown in **Figure TA 4-5** is provided in **Table TA 4-16** at the end of this technical appendix.

For all alternatives and the CCS Comparative Baseline, and across the Average, Dry, and Critically Dry Flow Categories, the median shortages are generally similar when comparing results with conservation activity on and conservation activity off. In other words, modeled conservation activity does not greatly impact the median shortage. However, conservation activity does have a variety of effects on overall variability of shortage for the different action alternatives that include conservation mechanisms. The analysis below is organized by alternative. The minimal differences in the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives are not described.

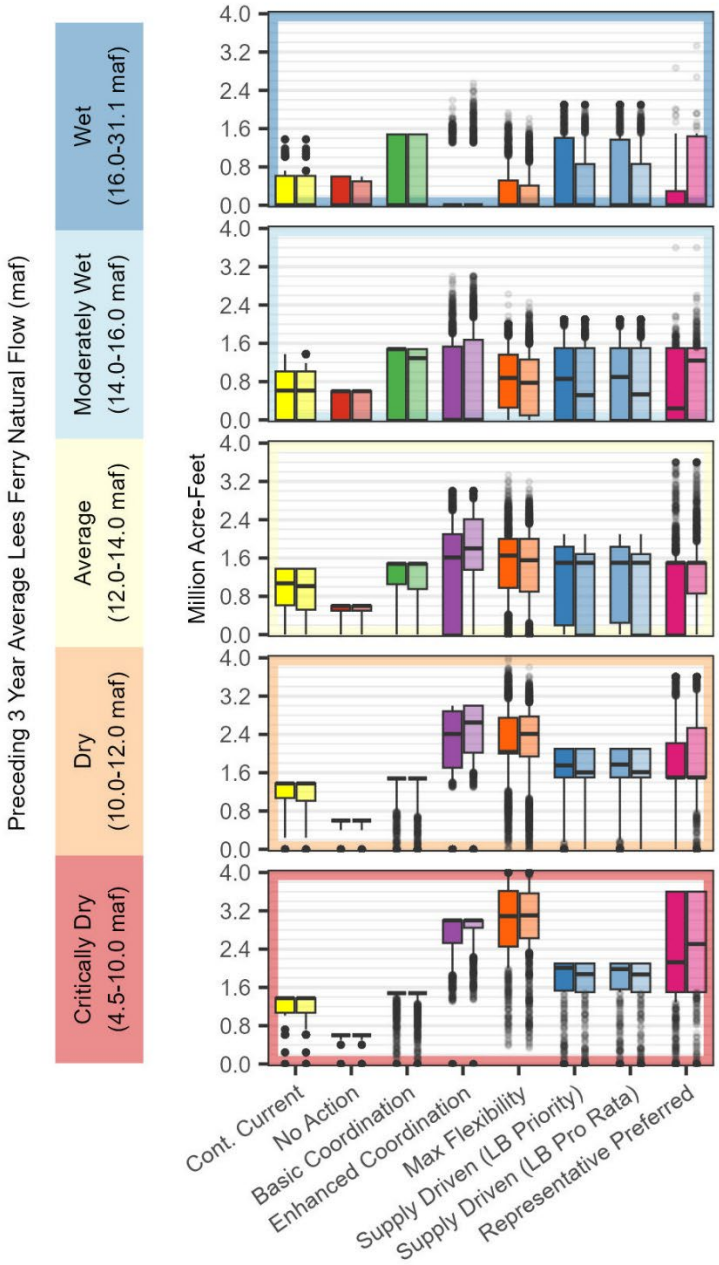
In the Enhanced Coordination Alternative, turning off conservation activity slightly increases shortage volumes in most percentiles in the Average, Dry, and Critically Dry Flow Categories. This is because conservation is not operationally neutral when determining shortages, so lower overall combined storage in Lake Powell and Lake Mead increases shortage volumes.

In the Average Flow Category, turning off conservation activity for the Maximum Operational Flexibility Alternative results in slightly lower shortages at the 25th and 10th percentiles. Similarly to the dynamics in the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), an operationally neutral conservation mechanism does not impact shortage determinations, but without conservation conversion or delivery to offset shortages, the shortages have a more positive impact on storage, which drives shortages along with hydrologic conditions. The relationship between conservation activity on versus off is different in the Dry and Critically Dry Flow Categories, with complex dynamics related to total system storage, hydrologic conditions, and changes in available conserved water impacting the comparisons of shortage with and without conservation activity. In the Critically Dry Flow Category, median shortage is nearly identical with slightly more variability if conservation activity is turned on.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) shows the same impacts of conservation activity on versus off. In the Average Flow Category, shortage is slightly lower at the 75th, 25th, and 10th percentiles with conservation turned off because, without the operationally neutral conservation that can be used to partially offset shortages, shortage volumes are actual delivery reductions and therefore have a more positive impact on Lake Mead elevation, which is the driver of shortage. This also explains the small differences in median shortages in the Dry and Critically Dry Flow Categories.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median shortage with conservation on and off is 1.5 maf. The interquartile range is large whether conservation activity is on or off due to the differences between the median and 75th percentiles. This range is slightly smaller with conservation on: the 25th and 75th percentiles of shortage are 1.5 maf and 2.2 maf, respectively, with conservation on and 1.5 maf and 2.5 maf, respectively, with conservation off.

Figure TA 4-5
Effects of Conservation Activity Modeling Assumptions on Lower Basin Shortage
(Conservation On: Darker Shade, Left; Conservation Off: Lighter Shade, Right)



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median shortage with conservation on is 2.1 maf and 2.5 maf with conservation off. The interquartile range is large whether conservation activity is on or off: the 25th and 75th percentiles of shortage are 1.5 maf and 3.6 maf, respectively, with conservation on and 1.5 maf and 3.6 maf, respectively, with conservation off.

Dead Pool-Related Reductions

Figure TA 4-6 shows the effects of conservation activity on annual Lake Mead dead pool-related reductions using paired boxplots. For each alternative, conservation activity is turned on for the left of each pair (darker color) and conservation activity is turned off for the right of each pair (lighter color). Unless otherwise specified, all analyses in this EIS have conservation activity turned on. A statistical summary of the data shown in **Figure TA 4-6** is provided in **Table TA 4-17** at the end of this technical appendix.

Across flow categories, the CCS Comparative Baseline, No Action, Basic Coordination, Enhanced Coordination, and Representative Preferred Alternatives are minimally affected by conservation activity. The discussion for **Figure TA 4-6** will focus on the Maximum Operational Flexibility Alternative and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches).

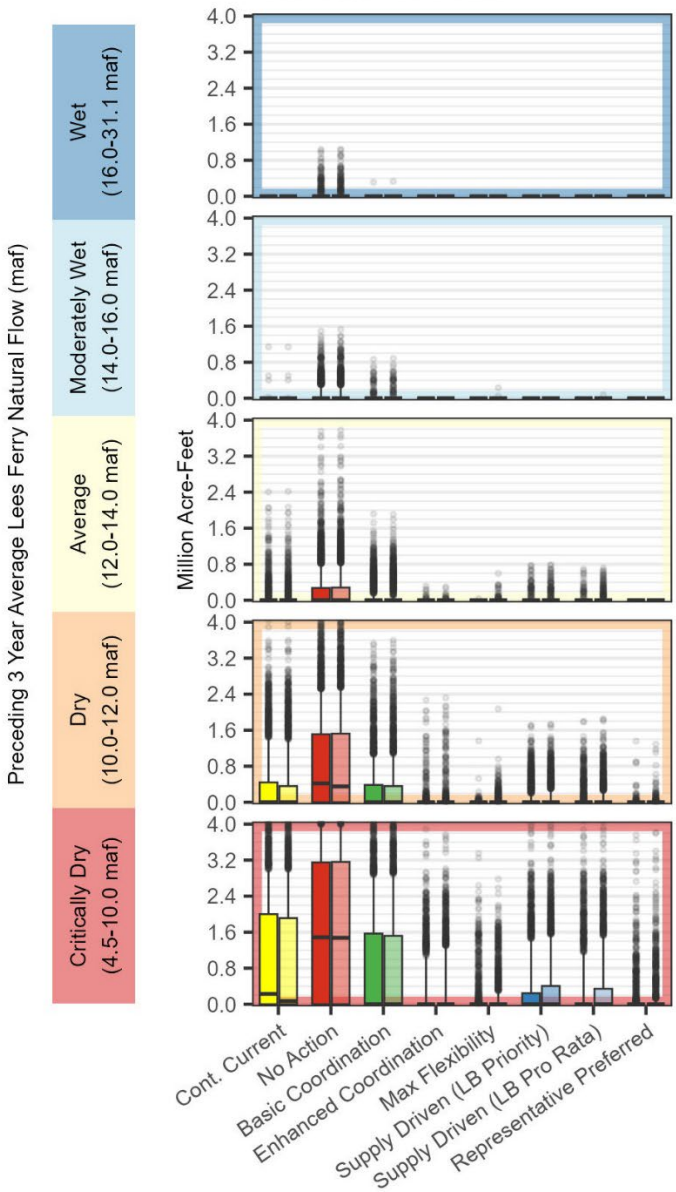
In the Average Flow Category, only the Maximum Operational Flexibility Alternative is notably affected by turning conservation activity off; instead of only one year having minimal dead pool-related reductions, turning off conservation activity results in a larger number of years with the reductions and a maximum volume of 0.6 maf. These outlier volumes are lower than the dead pool-related reductions seen in the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which do not show significant impacts related to conservation activity assumptions.

In the Dry Flow Category, the Maximum Operational Flexibility Alternative shows a large increase in the number of years with dead pool-related reductions when conservation activity is removed, and the maximum volume is 2.1 maf compared to 1.4 maf with conservation activity turned on. The conservation activity does not make a significant impact on the Supply Driven Alternative (LB Priority approach), but there is some impact in the Supply Driven Alternative (LB Pro Rata approach): the median dead pool-related reductions in this alternative are 0.0 maf in both cases, but the 90th percentile of years with conservation activity removed is 0.3 maf, compared with 0.0 maf with conservation activity turned on.

The differences for all three alternatives are largest in the Critically Dry Flow Category. For the Maximum Operational Flexibility, while median dead pool-related reductions are 0.0 maf and there are many non-zero outlier years both with and without conservation activity, the 90th percentile of years with conservation activity turned off is 0.3 maf. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) both show significant effects when conservation activity is turned off, but the difference is larger in the Supply Driven Alternative (LB Pro Rata approach), especially comparing 75th percentiles: with conservation activity on, the 75th percentile is 0.0 maf and with conservation activity removed, the 75th percentile is 0.3 maf.

Figure TA 4-6
Effects of Conservation Activity Modeling Assumptions on Lake Mead Dead Pool-Related Reductions

(Conservation On: Darker Shade, Left; Conservation Off: Lighter Shade, Right)



Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Depletions

Figure TA 4-7 shows the effects of conservation activity on annual Lower Basin depletions using paired boxplots. The right-hand vertical axis shows depletions as the percent of apportionment and the left-hand axis shows volume. Results will be described using percent of apportionment. For each alternative, conservation activity is turned on for the left of each pair (darker color) and conservation activity is turned off for the right of each pair (lighter color). Unless otherwise specified, all analyses in this EIS have conservation activity turned on. A statistical summary of the data shown in **Figure TA 4-7** is provided in **Table TA 4-18** at the end of this technical appendix.

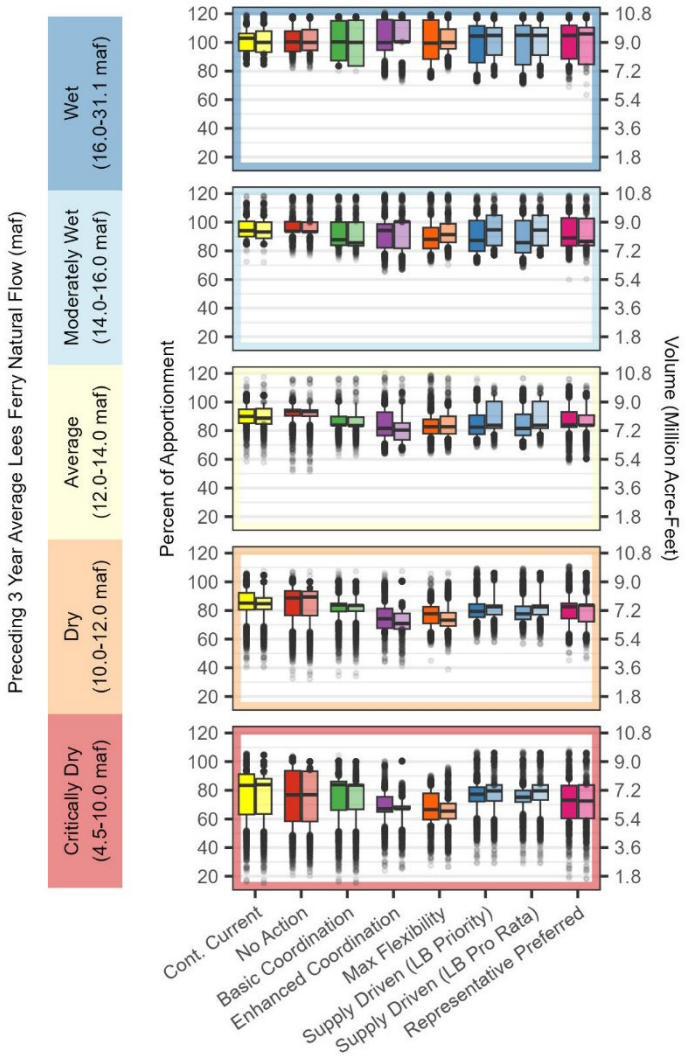
For all alternatives and the CCS Comparative Baseline, and across the Average, Dry and Critically Dry Flow Categories, the median depletions are similar when comparing results with conservation activity on and conservation activity off (no changes greater than 5 percent of apportionment). In other words, conservation activity does not greatly impact the median depletions. However, conservation activity does have a variety of effects on overall variability of depletions for the different action alternatives that include conservation mechanisms. The analysis below is organized by alternative. The minimal differences in the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives are not described.

Under the Enhanced Coordination Alternative, in the Average Flow Category, the median depletions with conservation activity on are 81.6 percent of apportionment and with conservation activity off, they are 80.4 percent of apportionment. While median depletions are similar with and without conservation activity, depletions are moderately to significantly lower in the Average, Dry, and Critically Dry Flow Categories when conservation is turned off. This occurs because the conservation mechanism is not operationally neutral with respect to Lower Basin shortage determinations, and without conserved water to increase reservoir elevations, shortages are higher, and depletions are lower.

In the Average Flow Category, the median depletions under the Maximum Operational Flexibility Alternative are 82.8 percent of apportionment with conservation activity on and 82.7 percent of apportionment and with conservation activity off. Overall, depletions are slightly higher with conservation activity turned on, but depletions are moderately lower without conservation activity in the Dry and Critically Dry Flow Categories. In the two drier flow categories, the absence of the ability to offset shortages by delivering conserved water reduces overall depletions.

Depletions under the two Supply Driven Alternative approaches respond similarly to conservation activity on versus off: in the Average Flow Category, Supply Driven Alternative (LB Priority approach) median depletions with conservation activity on and off are 82.4 and 83.7 percent of apportionment and the median depletions for Supply Driven Alternative (LB Pro Rata approach) are 81.6 and 83.7 percent of apportionment, respectively, with conservation activity turned on and off. The 25th percentile of depletions is higher with no conservation activity and in the 75th percentile depletions are 10 percent higher in the Average Flow Category. In this flow category, shortages are similar with conservation on and off (see **Figure TA 4-5**) but without conservation, depletions are higher. In the Dry and Critically Dry Flow Categories, the differences in depletions with conservation on and off are smaller because of higher shortages and, in the conservation-on results, limited opportunity to conserve water while there is more delivery of previously conserved water.

Figure TA 4-7
Effects of Conservation Activity Modeling Assumptions on Lower Basin Depletions (Conservation On: Darker Shade, Left, Conservation Off: Lighter Shade, Right)



Note: The modeled annual Lower Basin depletions include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median depletion with conservation on is 82.6 percent of apportionment and 83.7 percent of apportionment with conservation off. The interquartile range is relatively large whether conservation activity is on or off due to the differences between the median and 25th percentiles; the 25th and 75th percentiles of depletions are 74.4 and 85.0 percent, respectively, with conservation on, and 72.2 and 83.7 percent, respectively, with conservation off.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median depletion with conservation on is 73.1 percent of apportionment and 72.5 percent of apportionment with conservation off. The interquartile range is relatively large whether conservation activity is on or off; the 25th and 75th percentiles of depletions are 60.4 and 83.3 percent, respectively, with conservation on, and 60.4 and 83.7 percent, respectively, with conservation off.

Shortage

This section compares all the alternatives and the CCS Comparative Baseline with respect to shortages to each of the Lower Division States and Mexico.

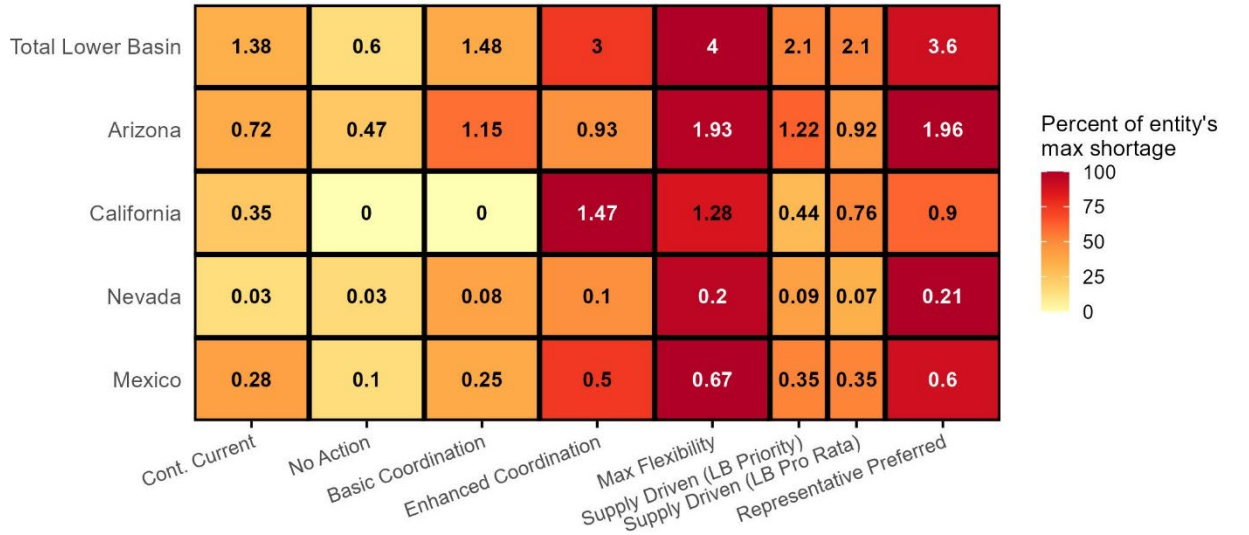
Maximum Shortage

Figure TA 4-8 compares alternatives based on the maximum shortage volume applied to the total Lower Basin and to each state and Mexico. The rows correspond to the entire Lower Basin (top row) and to different states or Mexico, and the columns correspond to different alternatives. Under each alternative, the shortages per state and Mexico sum to the total Lower Basin shortage shown in the top row[3]. Because the alternatives have different maximum volumes and also different distributions of shortage, each row has an independent color scale to facilitate identifying the maximum shortage to each entity: the darkest color in each row identifies the alternative that produces the maximum shortage for that entity. Under the CCS Comparative Baseline, DCP contributions and Binational Water Scarcity Contingency Plan savings are counted as shortages, though the required volumes are recoverable under certain conditions.

For all entities except California, either the Maximum Operational Flexibility Alternative or Representative Preferred Alternative imposes the largest maximum shortages. (Note that, as demonstrated by the 2027-2028 Operating Guidelines, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative.) The Enhanced Coordination Alternative is highest for California. For all entities, the No Action Alternative imposes the lowest (or is tied for lowest in Nevada and California) maximum shortage. California takes its largest shortage under the Enhanced Coordination Alternative, due to its pro rata approach to shortage distribution and large total shortage volumes.

[3] The sum of individual entities' volumes is different than the Total Lower Basin volumes for the Maximum Operational Flexibility and Representative Preferred Alternatives due to rounding values to two decimal places. The Total Lower Basin volume is correct.

Figure TA 4-8
Maximum Shortage (maf)

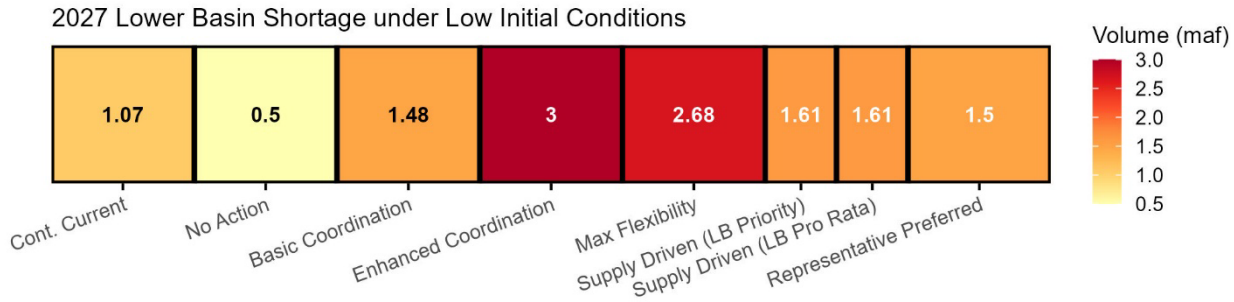


Note: Lower Basin shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

First Year Shortage

Figure TA 4-9 compares each alternative's 2027 Lower Basin shortage volume based on the modeled initial reservoir conditions. The color scale represents volume of shortage; darker colors correspond to the higher shortages.

Figure TA 4-9
Lower Basin Shortage in 2027



Note: Lower Basin shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In 2027, the largest Lower Basin shortages would be imposed by the Enhanced Coordination Alternative, while the No Action Alternative would impose the lowest shortages. The Representative Preferred Alternative would impose 1.5 maf of shortage.

Annual Lower Basin Shortage

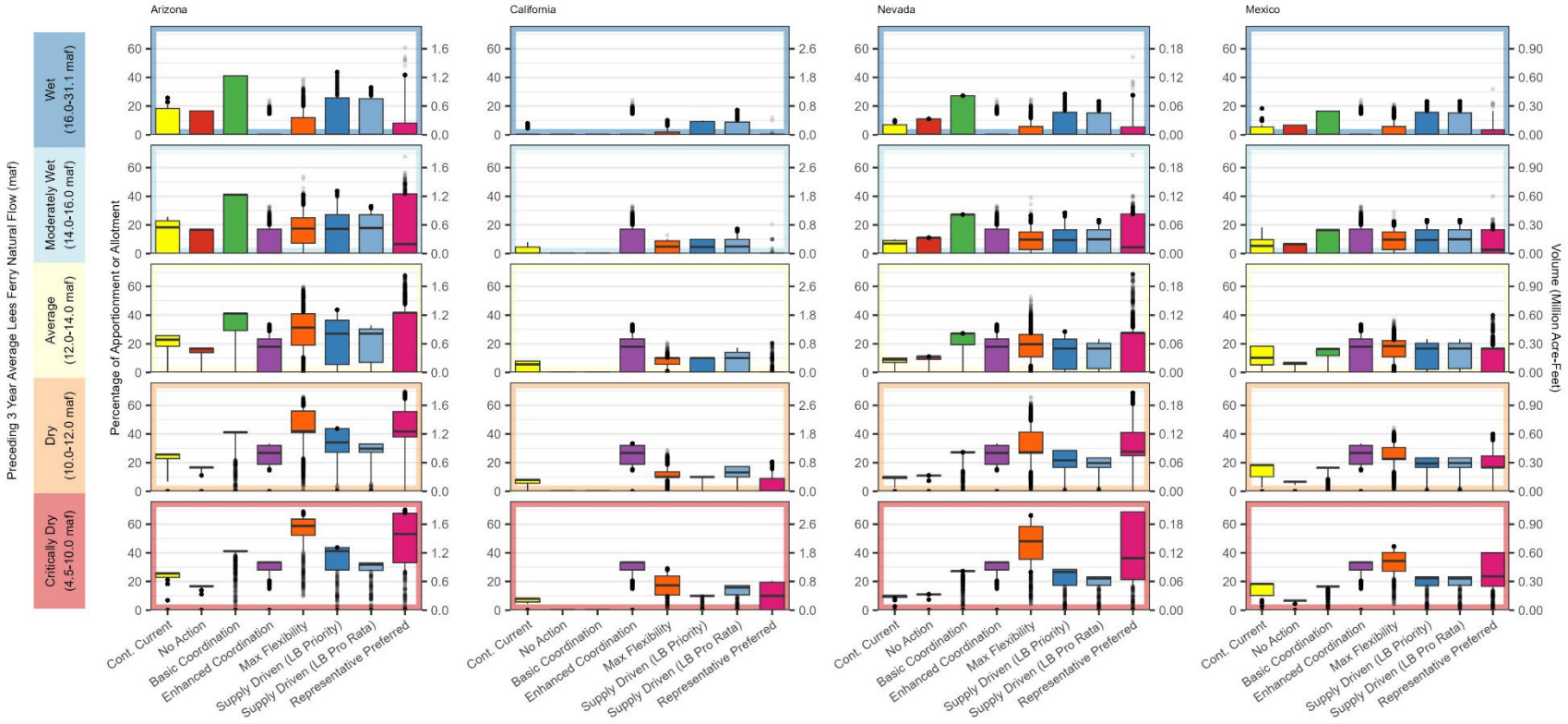
Figure TA 4-10 shows shortages to each Lower Division State and Mexico using four columns of conditional boxplots. The vertical axis for each state's column is scaled based on its respective volume of apportionment or allotment; the percent apportionment is shown on the left side of each column, and the absolute volume of shortage is shown on the right. Results will be described using percent of apportionment. Statistical summaries of the data shown in **Figure TA 4-10** are provided in **Table TA 4-19**, **Table TA 4-23**, **Table TA 4-29**, and **Table TA 4-37** at the end of this technical appendix.

Arizona, Nevada, and Mexico show similar relationships between alternatives across flow categories and are described together. In the Average Flow Category, the CCS Comparative Baseline and the No Action Alternative generally have the lowest median shortages, between 6.7 percent of allotment (Mexico, No Action Alternative) to 22.9 percent of apportionment (Arizona, CCS Comparative Baseline). These alternatives also show relatively low variability from the 25th to 75th percentiles, except for CCS Comparative Baseline for Mexico, which ranges from 5.3 percent to 18.3 percent of allotment. Recall that low shortages in **Figure TA 4-10** are associated with large and frequent dead pool–related reductions (see **Figure TA 4-1**, **Figure TA 4-2**, and **Figure TA 4-3**). Under the Basic Coordination Alternative, 50 percent of years have the maximum shortage volume in Arizona and Nevada and Mexico shortages of 41.1 percent, 27.2 percent and 16.4 percent of apportionment or allotment, respectively. The Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have similar median shortage percentages in Mexico and Nevada, around 20 percent, but Arizona takes shortages at a higher percentage of apportionment in these alternatives, around 30 percent. The Enhanced Coordination Alternative has exactly the same median shortage (17.9 percent of apportionment) and variability (25th and 75th percentiles of 0.0 and 23.3 percent of apportionment, respectively) across all entities since shortages are distributed using a pro rata approach.

In the Dry Flow Category, median shortages for Arizona, Nevada, and Mexico generally increase, and variability generally decreases. The Critically Dry Flow Category continues this shift, with most alternatives showing median shortages at the maximum shortage possible and some lower end variability. The exception in this category is the Maximum Operational Flexibility Alternative, which only reaches its largest shortages in high outliers and has large variability.

Shortages in California exhibit different patterns from the other three entities due to the shortage distribution methods associated with each alternative. The No Action and Basic Coordination Alternatives apply a priority distribution scheme, but the total Lower Basin shortages are low enough that they do not impose any shortages on California. In the Average Flow Category, the Enhanced Coordination Alternative shows the highest median shortage (17.9 percent of apportionment) because it uses a pro rata distribution scheme and it also has the most variability among the alternatives. The Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have median shortages of 10.0 percent of apportionment.

Figure TA 4-10
Calendar Year Shortage by State and Water Delivery Reductions to Mexico



Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

In the Critically Dry Flow Category, the CCS Comparative Baseline and Supply Driven Alternative (LB Priority approach) show median shortages of 8.0 and 10.0 percent of California's apportionment, respectively. The Supply Driven (LB Pro Rata approach) and Maximum Operational Flexibility Alternatives have median shortages of 15.8 and 17.3 percent of apportionment, respectively. The Enhanced Coordination Alternative has the highest median shortages of 33.3 percent of California's apportionment.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median calendar year shortage for Arizona is 41.7 percent, and the 25th to 75th percentiles range from 38.0 to 55.6 percent. For California, the median shortage is 0.0 percent with a 75th percentile of 8.9 percent. For Nevada, the median shortage is 27.6 percent, and the 25th to 75th percentiles range from 24.9 to 41.0 percent. For Mexico, the median water delivery reduction is 16.7 percent, and the 25th to 75th percentiles range from 16.7 to 24.6 percent.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median calendar year shortage for Arizona is 53.1 percent, and the 25th to 75th percentiles range from 33.1 to 67.6 percent. For California, the median shortage is 10.0 percent, and the 25th to 75th percentiles range from 0.0 to 19.5 percent. For Nevada, the median shortage is 36.3 percent, and the 25th to 75th percentiles range from 21.4 to 68.5 percent. For Mexico, the median water delivery reduction is 23.6 percent, and the 25th to 75th percentiles range from 16.7 to 40.0 percent.

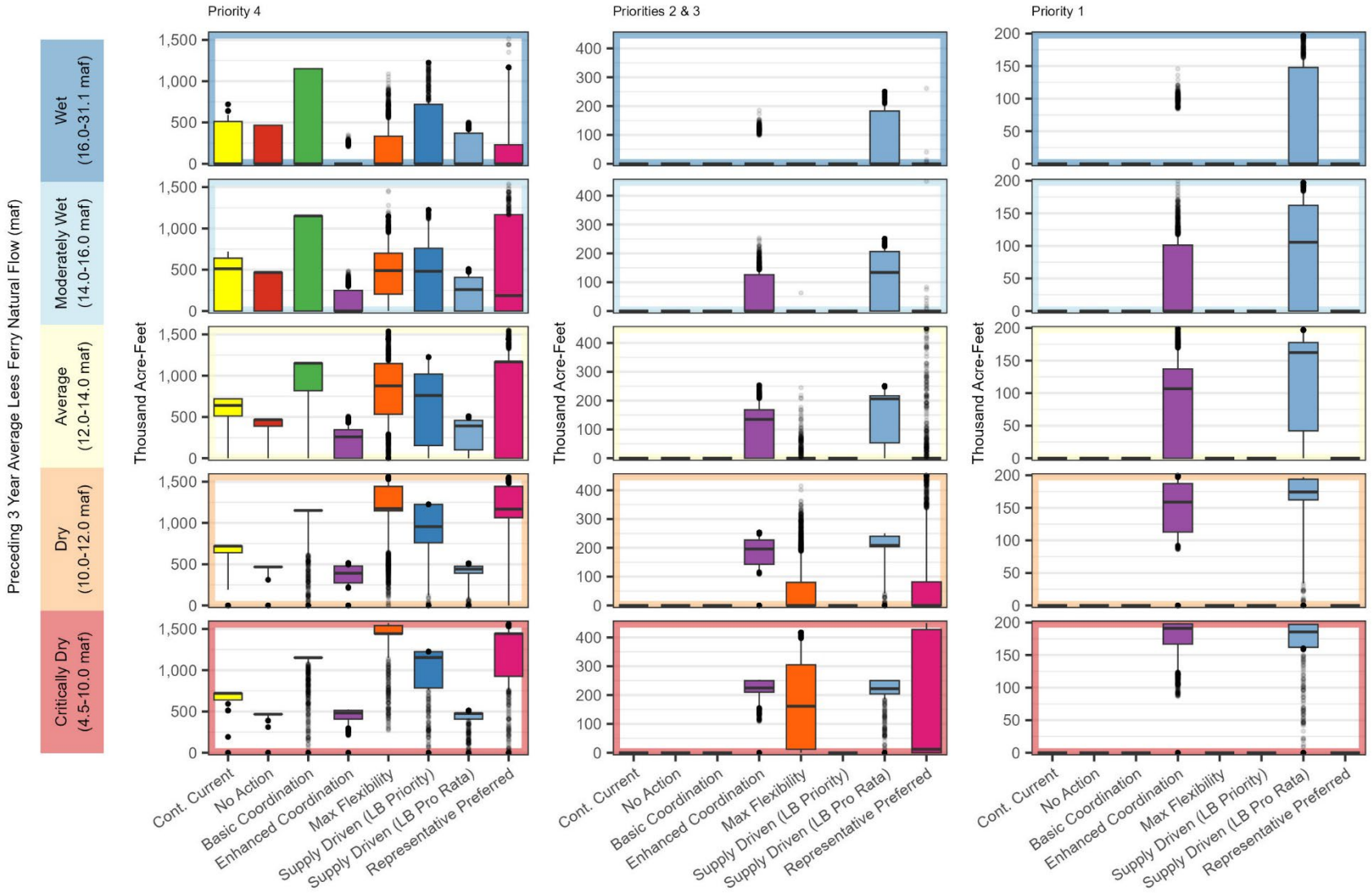
Annual Shortage by State and Priority

Arizona

Figure TA 4-11 compares the shortages to different priority groups in Arizona using three columns of conditional boxplots, a column for each priority within the state; Priorities 2 and 3 are co-equal. The vertical axis for each column is scaled based on the volume of shortages applied to the priority group. The sum of the shortages across priority groups (i.e., the sum of the columns in **Figure TA 4-11**) is shown in the previous figure, **Figure TA 4-10**. Statistical summaries of the data shown in **Figure TA 4-11** are provided in **Table TA 4-20** through **Table TA 4-22** at the end of this technical appendix.

All alternatives apply shortages to Priority 4 users, the most junior users in Arizona. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives impose shortages on Priorities 1, 2, and 3 users because they use pro rata-based approaches to distributing shortages, and the shortages under the Supply Driven Alternative (LB Pro Rata approach) are slightly higher because of how shortages are distributed across states. The Maximum Operational Flexibility and Representative Preferred Alternatives result in shortages to Priority 2 and 3 users because, while they use priority-based distribution methods, the total Lower Basin shortage volumes are large enough to extend to these users. The remaining discussion will focus primarily on Priority 4 users.

Figure TA 4-11
Annual Shortage for Arizona



In the Average Flow Category, the Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives have median Priority 4 shortages of 876.5 and 760.0 kaf, respectively, and both have wide variability between their 25th and 75th percentiles. The Basic Coordination, Supply Driven (LB Pro Rata approach) and Enhanced Coordination Alternatives have less variability, with median shortages of 1,151.6 kaf, 391.6 and 259.5 kaf, respectively. The No Action Alternative and CCS Comparative Baseline have low variability with medians of 466.8 and 640.0 kaf, respectively.

As conditions get drier, median shortages to Priority 4 users increase, and variability decreases. In the Critically Dry Flow Category, the Maximum Operational Flexibility, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives show similar volumes of shortage to Arizona Priority 4 users at 1,442.6, 1,151.6 and 1,153.0 kaf, respectively. The No Action, Enhanced Coordination, and Supply Driven (LB Pro Rata approach) Alternatives have similar median shortages, with volumes between 466.9 and 480.9 kaf.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For Priority 4 users, the median state shortage is 1,167.1 kaf, and the 25th to 75th percentiles range from 1,063.6 to 1,442.6 kaf, respectively. For Priority 2 and 3 (co-equal) users, the median is 0.0 kaf, and the 75th percentile is 82.0 kaf. Priority 1 users do not take shortage under this alternative.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For Priority 4 users, the median state shortage is 1,442.6 kaf, and the 25th to 75th percentiles range from 926.3 to 1,442.6 kaf. For Priority 2 and 3 users, the median shortage is 12.0 kaf, and the 25th to 75th percentiles range from 0.0 to 427.5 kaf. Priority 1 users do not take shortage under this alternative.

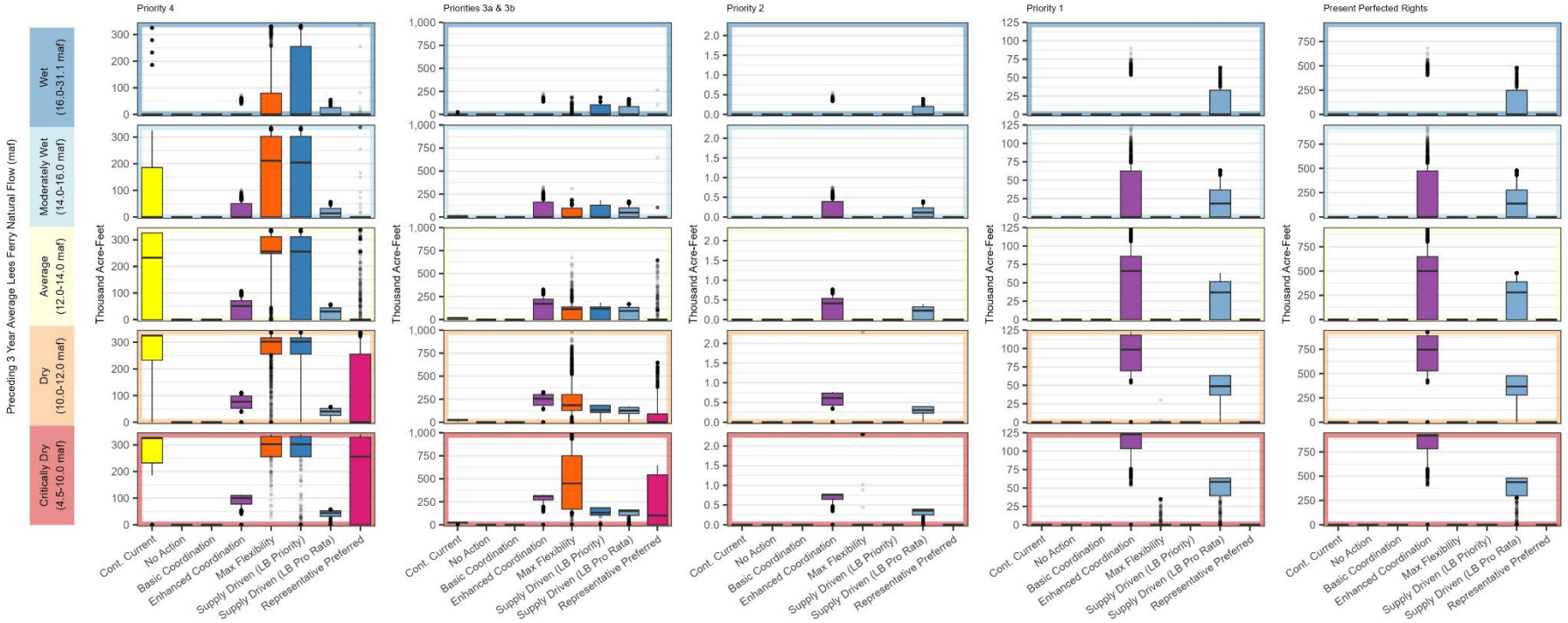
California

Figure TA 4-12 compares the shortages to different priority groups in California using five columns of conditional boxplots, a column for each priority within the state. The vertical axis for each column is scaled based on the volume of shortages applied to the priority group. The sum of the shortages across priority groups (i.e., the sum of the columns in **Figure TA 4-12**) is shown in **Figure TA 4-10**. Statistical summaries of the data shown in **Figure TA 4-12** are provided in **Table TA 4-24** through **Table TA 4-28** at the end of this technical appendix.

The No Action and Basic Coordination Alternatives do not apply shortages to California water users due to their combinations of low maximum Lower Basin shortages and use of the priority system to distribute the shortages. However, recall that low maximum Lower Basin shortage volumes translate to higher volumes of dead pool-related reductions (see **Figure TA 4-12**).

The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives use pro rata-based distribution approaches, so these alternatives apply shortages to senior priority groups while other alternatives do not. In the Average, Dry, and Critically Dry Flow Categories, the Enhanced Coordination Alternative applies higher median shortages than the Supply Driven Alternative (LB Pro Rata approach) for Priorities 1 and 2 and PPRs. The Maximum Operational Flexibility Alternative also applies shortages to these groups in a small number of years in the Dry and Critically Dry Flow Categories. The remaining discussion will focus on Priority 4 and the co-equal Priorities 3a and 3b.

Figure TA 4-12
Annual Shortage for California



Priority 4 users are the most junior and experience the largest volumes of shortages relative to their total volume of rights. In the Average, Dry and Critically Dry flow categories, the Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives have the same median shortages of 255.7, 302.7 and 302.7 kaf, respectively, due to using the same distribution method. The Supply Driven Alternative (LB Priority approach) has a wider interquartile range in the Average Flow Category, but the interquartile ranges are the same for these two alternatives in the Dry and Critically Dry flow categories. The Supply Driven (LB Pro Rata approach) and Enhanced Coordination Alternatives both have lower medians and smaller ranges than the other alternatives that short these users due to their pro rata-based distribution methods, but the Enhanced Coordination Alternative has higher medians in all flow categories (50.8, 76.5, and 100.0 kaf in Average, Dry, and Critically Dry, respectively) than the Supply Driven Alternative (LB Pro Rata approach) (30.3, 40.1, and 44.0 kaf in Average, Dry, and Critically Dry, respectively).

The Representative Preferred Alternative exhibits the following shortages to Priority 4 users in the Dry Flow Category: the median shortage is 0.0 kaf, and there is large variability within the interquartile range, especially comparing the 75th percentile volume of 255.7 kaf to the median. The Representative Preferred Alternative exhibits the following shortages to Priority 4 users in the Critically Dry Flow Category: the median shortage is 255.7 kaf, and there is large variability within the interquartile range, with the 25th percentile of shortages being 0.0 kaf and the 75th percentile of shortages being 328.2 kaf.

Priorities 3a and 3b (co-equal) users have relatively small differences in median shortages across alternatives that short these users in the Average and Dry flow categories; excluding the Representative Preferred Alternative (described later), the median shortages range from 172.3 kaf to 93.6 kaf in the Average Flow Category under Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, respectively. The median shortages in the Dry Flow Category range from 254.1 kaf to 125.9 kaf under these same two respective alternatives. In the Critically Dry Flow Category, comparisons between alternatives are similar, but with higher medians and less variability, with the exception of the Maximum Operational Flexibility Alternative, which has the highest median shortage of 448.7 kaf and large variability, with 168.7 kaf of shortage at the 25th percentile and 749.7 kaf at the 75th percentile.

The Representative Preferred Alternative exhibits the following shortages to Priorities 3a and 3b users in the Dry Flow Category: the median shortage is 0.0 kaf, and with some variability within the interquartile range when comparing the 75th percentile volume of 89.0 kaf to the median. The Representative Preferred Alternative exhibits the following shortages to Priorities 3a and 3b users in the Critically Dry Flow Category: the median shortage is 100.4 kaf, and there is large variability within the interquartile range, with the 25th percentile of shortages being 0.0 kaf and the 75th percentile of shortages being 542.9 kaf.

Nevada

Figure TA 4-13 compares the shortages to different priority groups in Nevada using four columns of conditional boxplots, a column for each priority group within the state. The vertical axis for each column is scaled based on the volume of shortages applied to the priority group. The sum of the shortages across priority groups (i.e., the sum of the columns in **Figure TA 4-13**) is shown in **Figure TA 4-10**. Statistical summaries of the data shown in **Figure TA 4-13** are provided in **Table TA 4-30** through **Table TA 4-33** at the end of this technical appendix.

A comparison of the vertical axis units and ranges for each column shows that the Priority 8 group captures the vast majority of water rights in Nevada, so discussion will focus on the leftmost column. The other priority groups receive shortages under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives because of the pro rata-based shortage distribution methods.

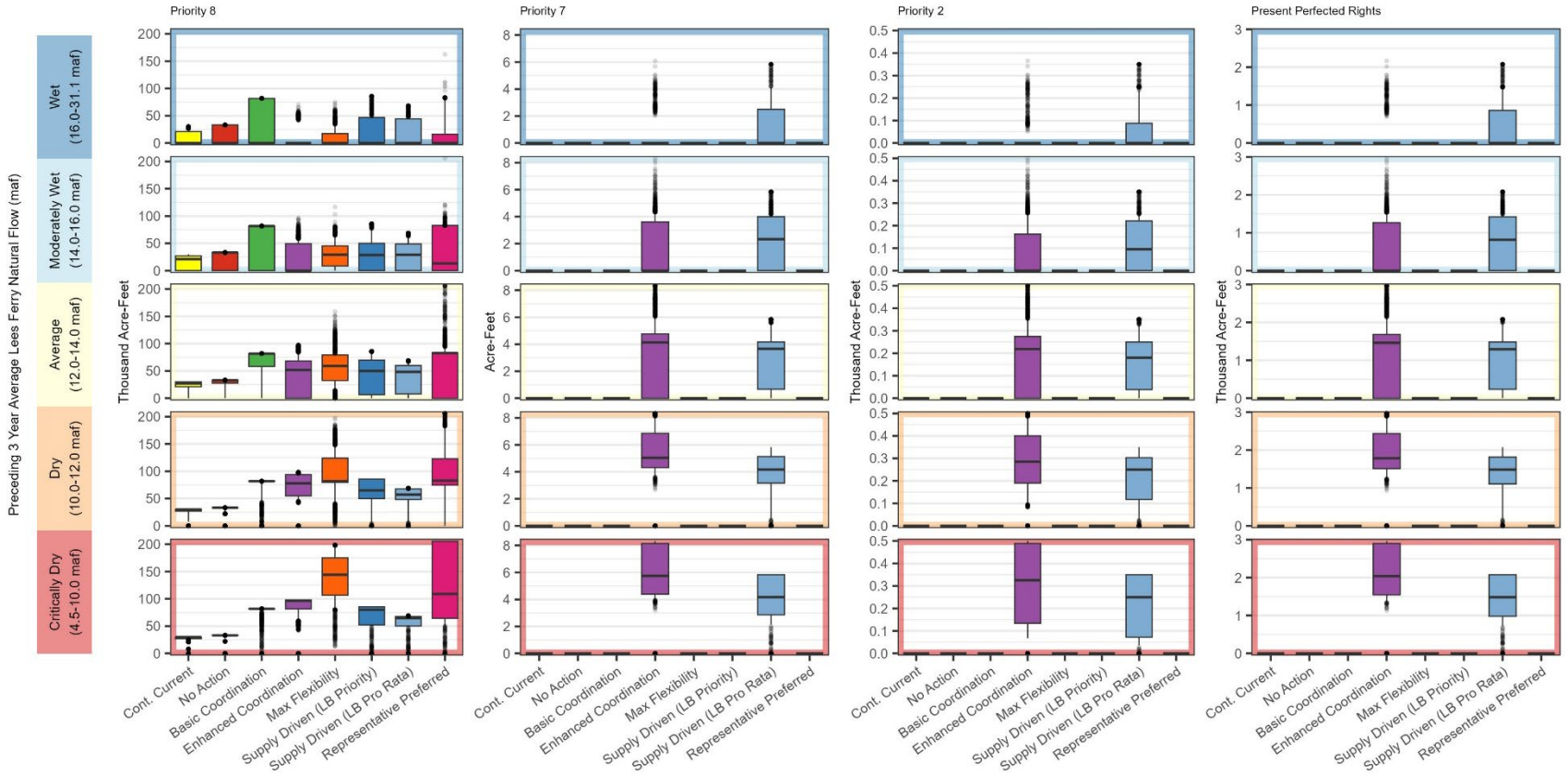
In the Average Flow Category, median shortage volumes are clustered in three groups: the Basic Coordination and Representative Preferred Alternatives impose 81.7 and 82.8 kaf, respectively; the Maximum Operational Flexibility, Enhanced Coordination, Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) Alternatives impose 58.9, 51.9, 50.0, and 48.3 kaf, respectively; the CCS Comparative Baseline and the No Action Alternative impose 27.0 and 33.1 kaf, respectively. The action alternatives besides the Basic Coordination Alternative show similar variability based on the differences between their respective 25th and 75th percentile shortages; the Basic Coordination Alternative has less variability.

As conditions get drier, median shortages for the action alternatives generally increase. Compared with the Average Flow Category, variability in the Critically Dry Flow Category increases for the Maximum Operational Flexibility and Representative Preferred Alternatives, while it decreases for the other alternatives. In the Critically Dry Flow Category, the Basic Coordination Alternative has the same median shortage of 81.7 kaf because the maximum shortage is low enough that it was being applied even in Average flow conditions. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives have median shortages of 96.5, 144.1, 79.8, and 64.6 kaf, respectively.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For Priority 8 users, the median state shortage is 82.8 kaf, and the 25th to 75th percentiles range from 74.7 to 122.9 kaf. No other priority groups take shortage under this alternative.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For Priority 8 users, the median state shortage is 108.9 kaf, and the 25th to 75th percentiles range from 64.2 to 205.6 kaf. No other priority groups take shortage under this alternative.

Figure TA 4-13
Annual Shortage for Nevada



Annual Depletions

This section compares the annual depletions to the Lower Division States and Mexico across all alternatives and the CCS Comparative Baseline. Depletion (sometimes referred to as "total consumptive use") is the net amount of water used. It is calculated as the amount of water diverted from the river minus the return flow. Return flow is the portion of diverted water that is not consumed and returns to the river for subsequent downstream use. Depletions depend both on the total shortage volume as well as the approach used to distribute shortages among states, and also account for modeling assumptions related to voluntary conservation mechanisms.

In this section, dead pool-related reduction impacts are included in the figures and discussion.

Arizona

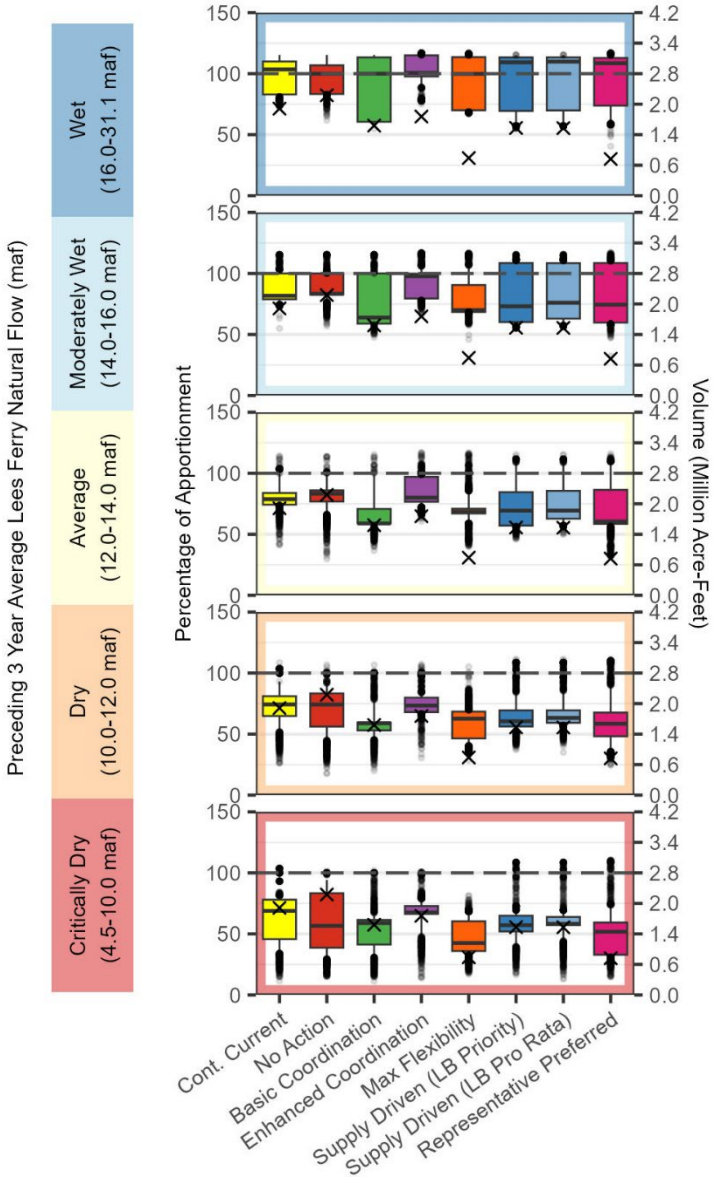
Figure TA 4-14 shows Arizona's depletions under each alternative using conditional boxplots. The results are plotted in terms of their percentage of the state's 2.8-maf apportionment (units shown on the left side of panels) and the volume of shortage (units shown on the right side of panels). A dashed line is included on each panel at 100 percent of apportionment. Results will be described using percent of apportionment. Each alternative includes an "X" marker indicating the smallest depletion volume that was *not* affected by dead pool–related reductions from Lake Mead; any data points below the marker were affected by infrastructure constraints at Lake Mead elevations near dead pool. The volume associated with the marker differs by alternative because shortage volumes vary among alternatives, which affects the occurrence and magnitude of dead pool-related reductions. A statistical summary of the data shown in **Figure TA 4-14** is provided in **Table TA 4-34** at the end of this technical appendix.

In the Average Flow Category, across the alternatives, Arizona's median depletions range from 83.3 percent of apportionment (No Action Alternative) to 58.9 percent (Basic Coordination Alternative). Generally, in this flow category, Arizona gets 100 percent of apportionment in only about 10 percent of years because the alternatives apply shortages in most of the years in this flow category (and conservation activity does not fully offset the shortages). The Enhanced Coordination Alternative has moderate variability and the highest 75th percentile of depletions due to the pro rata-based shortage distribution. In the No Action and Basic Coordination Alternatives, nearly 50 percent of years have depletions affected by dead pool-related reductions, while there are few or no years impacted by these reductions in the other alternatives. The Representative Preferred Alternative has similar variability to the Supply Driven Alternative (LB Priority approach) in the interquartile range because they distribute the use the same for the first 1.5 maf of shortage, but lower median depletions than that alternative due to having a larger maximum shortage volume.

Median depletions do not go down significantly from the Average Flow Category to the Dry Flow Category, but percentages of years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and 25th percentiles of depletions decrease significantly compared to the Average Flow Category in most alternatives due to large shortage volumes and limited availability of or access to conserved water to offset them. Across alternatives, the median depletions range from 67.5 percent of apportionment (Enhanced Coordination Alternative) to 42.5 percent of apportionment (Maximum Operational Flexibility Alternative). The CCS Comparative Baseline and the No Action, Basic Coordination, and Maximum Operational Flexibility Alternatives

show the largest decreases in their median and 25th percentile depletions. Near or above 50 percent of years under the CCS Comparative Baseline and the Basic Coordination and Supply Driven (LB Priority approach) Alternatives are affected by dead pool-related reductions, and approximately 75 percent of years are affected by these reductions under the No Action Alternative.

Figure TA 4-14
Annual Depletions in Arizona



Note: Depletion volumes below the "X" marker were affected by infrastructure constraints at Lake Mead elevations near dead pool.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median depletion by Arizona is 58.5 percent of apportionment, and the 25th to 75th percentiles range from 48.2 to 67.7 percent. Depletions in some outlier years (below the 10th percentile) are affected by dead pool at Lake Mead.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median depletion by Arizona is 51.8 percent of apportionment, and the 25th to 75th percentiles range from 32.9 to 59.3 percent. Depletions in approximately 10 percent of years are affected by dead pool at Lake Mead.

California

Figure TA 4-15 shows California's depletions under each alternative using conditional boxplots. The results are plotted in terms of their percentage of the state's 4.4-maf apportionment (units shown on the left side of panels) and the volume of shortage (units shown on the right side of panels). A dashed line is included on each panel at 100 percent of apportionment. Each alternative includes an "X" marker indicating the smallest depletion volume that was *not* affected by dead pool–related reductions from Lake Mead; any data points below the marker were affected by infrastructure constraints at Lake Mead elevations near dead pool. The volume associated with the marker differs by alternative because shortage volumes vary among alternatives, which affects the occurrence and magnitude of dead pool-related reductions. A statistical summary of the data shown in **Figure TA 4-15** is provided in **Table TA 4-35** at the end of this technical appendix.

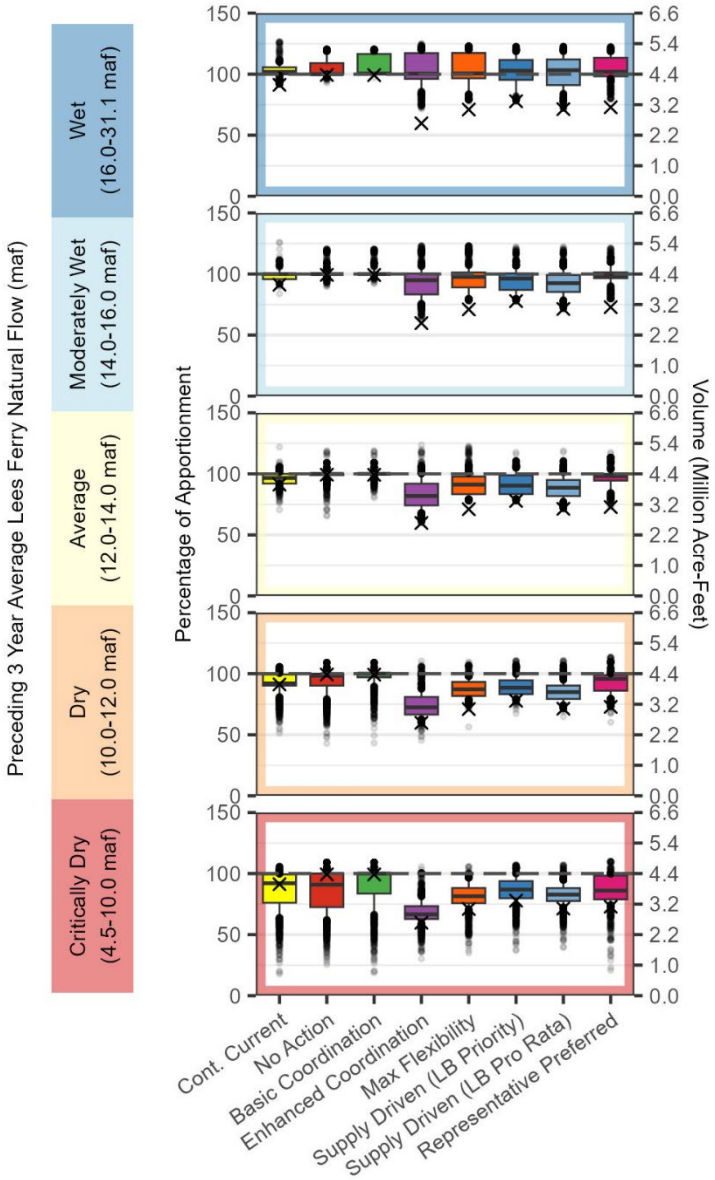
In the Average Flow Category, across the alternatives, California's median depletions range from 100.0 percent of apportionment (No Action and Basic Coordination Alternative) to 81.9 percent (Enhanced Coordination Alternative). In the No Action and Basic Coordination Alternatives, any depletions below 100 percent are associated with dead pool-related reductions. For the other alternatives, in this flow category, California gets at least 100 percent of apportionment in approximately 10 to 25 percent of years because the alternatives apply shortages in most of the years in this flow category (and conservation activity does not fully offset the shortages). The Enhanced Coordination Alternative has the highest variability and lowest median depletions due to the pro rata-based shortage distribution.

Except for the Enhanced Coordination Alternative, median depletions do not go down significantly from the Average Flow Category to the Critically Dry Flow Category because California takes a lower percentage of shortage than other entities, but percentages of years affected by dead pool-related reductions increase. Across alternatives, the median depletions in the Critically Dry Flow Category range from 100.0 percent of apportionment (Basic Coordination Alternative) to 66.6 percent of apportionment (Enhanced Coordination Alternative). Near or above 50 percent of years under the CCS Comparative Baseline and the Basic Coordination Alternative are affected by dead pool-related reductions, and approximately 75 percent of years are affected by these reductions under the No Action Alternative. Approximately 10 percent of years or fewer are affected by dead pool in the other alternatives.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median depletion by California is 95.8 percent of apportionment, and the 25th to

75th percentiles range from 86.1 to 98.9 percent. Depletions in some outlier years (below the 10th percentile) are affected by dead pool at Lake Mead.

Figure TA 4-15
Annual Depletions in California



Note: Depletion volumes below the "X" marker were affected by infrastructure constraints at Lake Mead elevations near dead pool.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median depletion by California is 86.0 percent of apportionment, and the 25th to 75th percentiles range from 78.9 to 98.3 percent. Depletions in fewer than 10 percent of years are affected by dead pool at Lake Mead.

Nevada

Figure TA 4-16 shows Nevada's depletions under each alternative using conditional boxplots. The results are plotted in terms of their percentage of the state's 300-kaf apportionment (units shown on the left side of panels) and the volume of shortage (units shown on the right side of panels). A dashed line is included on each panel at 100 percent of apportionment. Each alternative includes an "X" marker indicating the smallest depletion volume that was *not* affected by dead pool–related reductions from Lake Mead; any data points below the marker were affected by infrastructure constraints at Lake Mead elevations near dead pool. The volume associated with the marker differs by alternative because shortage volumes vary among alternatives, which affects the occurrence and magnitude of dead pool-related reductions. A statistical summary of the data shown in **Figure TA 4-16** is provided in **Table TA 4-36** at the end of this technical appendix.

In the Average Flow Category, across the alternatives, Nevada's median depletions range from 105.8 percent of apportionment (CCS Comparative Baseline) to 83.3 percent (Basic Coordination Alternative). Except for the Basic Coordination Alternative, in this flow category, Nevada gets at least 100 percent of apportionment in approximately 40 to 50 percent of years. This is a higher percent of years than either Arizona or California because of modeling assumptions about conservation activity. The Basic Coordination Alternative shows the lowest median depletions because it distributed shortage to Arizona and Nevada only. Except for CCS Comparative Baseline, the alternatives have similar variability.

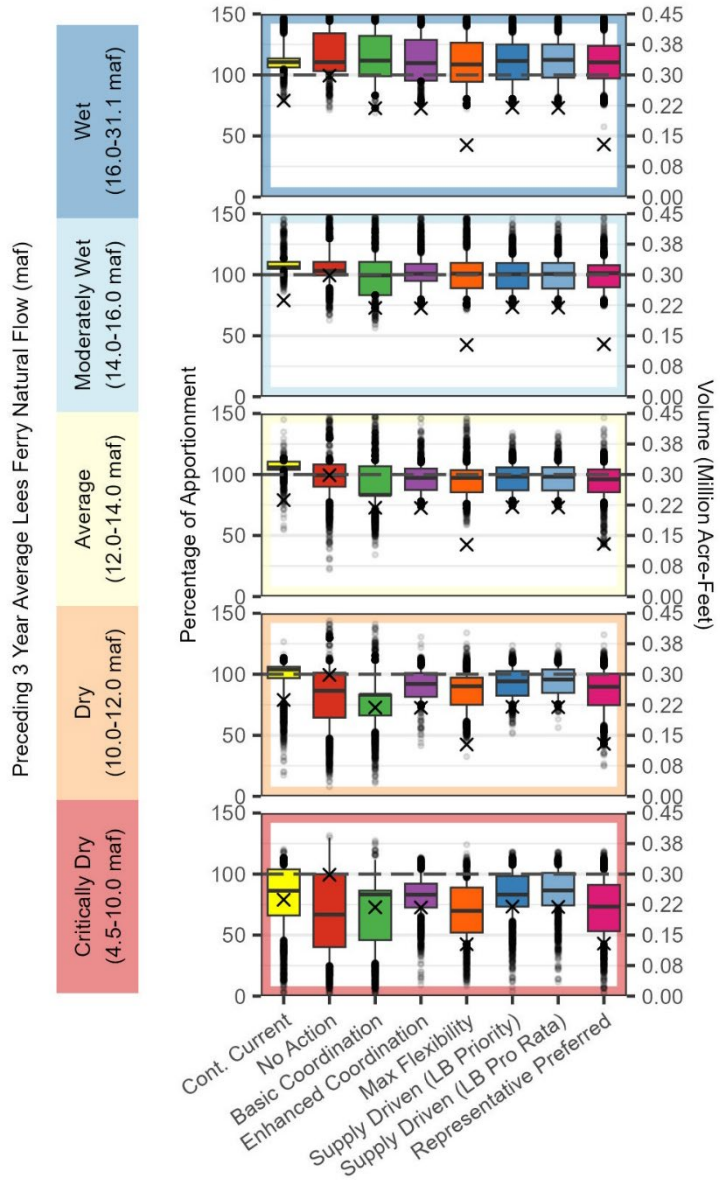
Median depletions do not go down significantly from the Average Flow Category to the Dry Flow Category, but percentages of years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and 25th percentiles of depletions decrease significantly compared to the Average Flow Category in most alternatives due to large shortage volumes and limited availability of or access to conserved water to offset them. The CCS Comparative Baseline and the Basic Coordination, Enhanced Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have similar median depletions around 85 percent of apportionment. The No Action, Maximum Operational Flexibility, and Representative Preferred Alternatives have similar median depletions, around 70 percent of apportionment. Near or above 50 percent of years under the CCS Comparative Baseline and the Basic Coordination Alternative are impacted by dead pool-related reductions, and 75 percent of years in the No Action Alternative are impacted by these reductions. The Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are impacted by dead pool in approximately 25 percent of years, and the Maximum Operational Flexibility Alternative is impacted by these reductions in approximately 10 percent of years.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median depletion by Nevada is 89.7 percent of apportionment, and the 25th to 75th percentiles range from 74.7 to 100.5 percent. Depletions in some outlier years (below the 10th percentile) are affected by dead pool at Lake Mead.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median depletion by Nevada is 73.3 percent of apportionment,

and the 25th to 75th percentiles range from 53.1 to 91.2 percent. Depletions in approximately 10 percent of years are affected by dead pool at Lake Mead.

Figure TA 4-16
Annual Depletions in Nevada



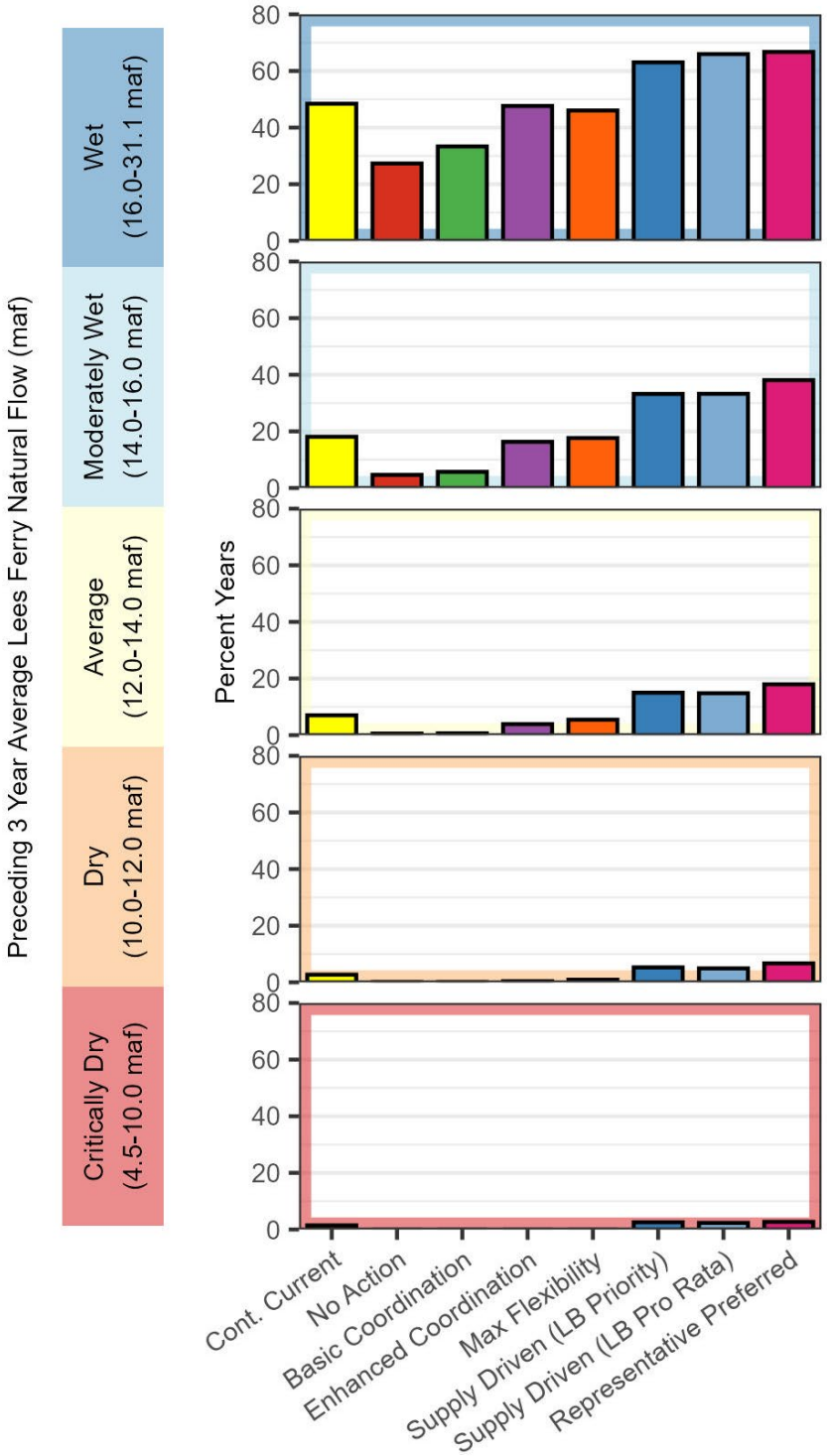
Note: Depletion volumes below the "X" marker were affected by infrastructure constraints at Lake Mead elevations near dead pool.

Surplus

Figure TA 4-17 below compares the alternatives with respect to frequency of surplus deliveries. Percents of years with surplus deliveries are broken out by different hydrologic conditions, categorized by preceding three-year average Lees Ferry natural flows. Because the frequency of surplus deliveries occurring in each flow category is shown and not the volume of surplus water

delivered, bars are used instead of boxplots. The height of the bar shows the percent of years when surplus deliveries occurred.

Figure TA 4-17
Percent of Years with Delivery Surplus



In the Average Flow Category, the Representative Preferred Alternative has the highest frequency of surplus deliveries at 18.0 percent of years, followed closely by the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which resulted in surplus deliveries in about 15 percent of years. The CCS Comparative Baseline and the Enhanced Coordination and Maximum Operational Flexibility Alternatives resulted in surplus deliveries in fewer than 10 percent of years.

All alternatives resulted in surplus deliveries in fewer than 10 percent of the years in the Dry Flow Category, and only the CCS Comparative Baseline, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Representative Preferred Alternative had any incidence of surplus deliveries in the Critically Dry Flow Category (fewer than 3 percent of years).

TA 4.2.5 Issue 4: Deliveries to Mexico

Issue 4 addresses how operational activities affect deliveries to Mexico. This will be achieved by comparison of the various action alternatives to the No Action Alternative and CCS Comparative Baseline for the following metrics:

- Annual water delivery reductions to Mexico
- Annual depletions in Mexico

Refer to **Appendix N**, International Border Region of the Colorado River, for additional information regarding water deliveries to the International Border Region.

Deliveries to Mexico under the CCS Comparative Baseline are established in Minute 319 and Minute 323, Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin in 2017 (International Boundary and Water Commission 2017), which identify maximum reductions to Mexico's delivery to 275 kaf, including volumes of Mexico's recoverable water savings. All alternatives assume a 1.5 maf annual allotment to Mexico but differ in how reductions and surplus are determined. Under the No Action Alternative, determination of deliveries to Mexico is made in accordance with the 1944 Mexican Water Treaty.

Water delivery reductions to Mexico under all the alternatives, except for the CCS Comparative Baseline, are modeled in proportion to Lower Division States shortage. All alternatives assume that a consistent 16.67 percent of all Lower Basin shortages are applied to water deliveries to Mexico on an annual basis. Refer to **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, and **Appendix N**, International Border Region of the Colorado River, for specifics.

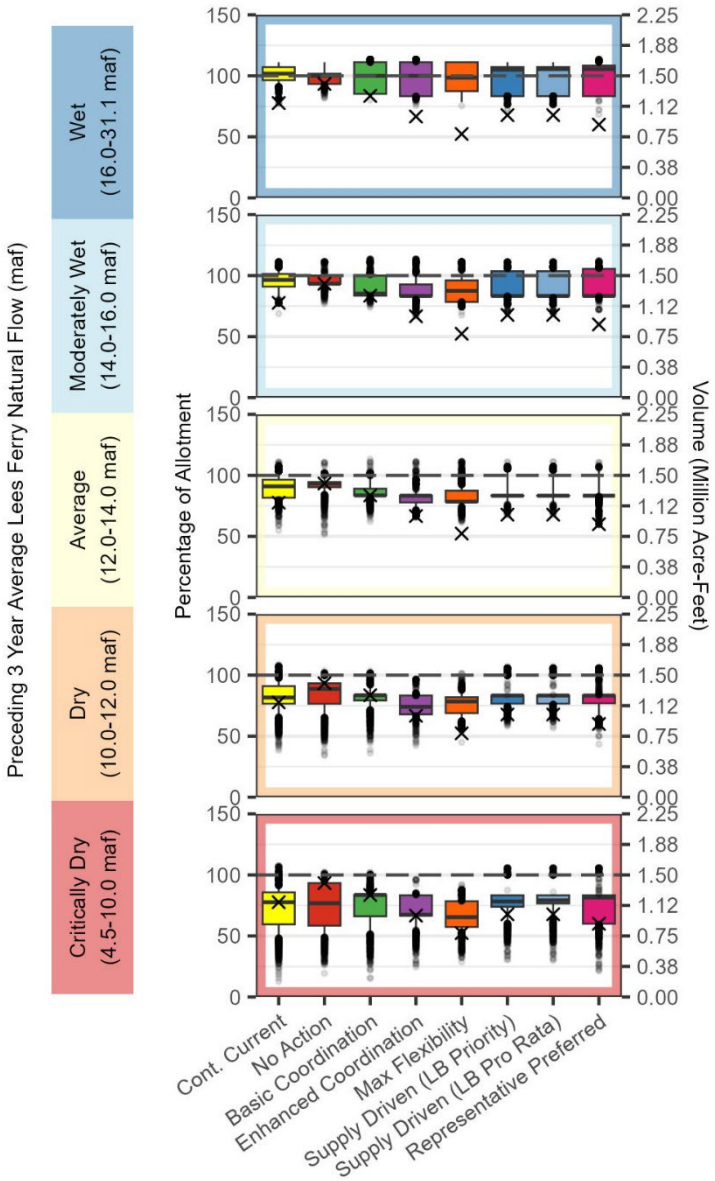
Annual Water Delivery Reductions

Refer to **Figure TA 4-10** for the conditional boxplots showing reductions to Mexico. A statistical summary of the data shown in **Figure TA 4-10** is provided in **Table TA 4-37** at the end of this technical appendix.

Annual Depletions

Figure TA 4-18 shows Mexico's depletions under each alternative using conditional boxplots. The results are plotted in terms of their percentage of the 1.5-maf allotment (units shown on the left side of panels) and the volume of shortage (units shown on the right side of panels). A dashed line is included on each panel at 100 percent of allotment. Each alternative includes an "X" marker

Figure TA 4-18
Annual Depletions in Mexico



Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.
Note: Depletion volumes below the "X" marker were affected by infrastructure constraints at Lake Mead elevations near dead pool.

indicating the smallest depletion volume that was *not* affected by dead pool–related reductions from Lake Mead; any data points below the marker were affected by infrastructure constraints at Lake Mead elevations near dead pool. The volume associated with the marker differs by alternative because shortage volumes vary among alternatives, which affects the occurrence and magnitude of dead pool-related reductions. A statistical summary of the data shown in **Figure TA 4-18** is provided in **Table TA 4-38** at the end of this technical appendix.

In the Average Flow Category, across the alternatives, Mexico's median depletions range from 93.3 percent of allotment (No Action Alternative) to 78.5 percent (Maximum Operational Flexibility Alternative). Generally, in this flow category, Mexico gets at least 100 percent of allotment in only about 10 percent of years or fewer because the alternatives apply delivery reductions in most of the years in this flow category (and conservation activity does not fully offset the reductions). In the No Action and Basic Coordination Alternatives, nearly 50 percent of years have depletions affected by dead pool-related reductions, while there are few or no years impacted by these reductions in the other alternatives.

Median depletions do not go down significantly from the Average Flow Category to the Dry Flow Category, but percentages of years affected by dead pool-related reductions increase. In the Critically Dry Flow Category, median and 25th percentiles of depletions decrease significantly compared to the Average Flow Category in most alternatives due to large shortage volumes and limited availability of or access to conserved water to offset them. The CCS Comparative Baseline, the No Action and Basic Coordination Alternatives, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and the Representative Preferred Alternative have similar median depletions around 80 percent of allotment. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have similar median depletions, around 66 percent of allotment. Near or above 50 percent of years under the CCS Comparative Baseline and the Basic Coordination Alternative are impacted by dead pool-related reductions, and 75 percent of years in the No Action Alternative are impacted by these reductions. The Enhanced Coordination and Representative Preferred Alternatives are impacted by dead pool in approximately 25 percent of years, and the Maximum Operational Flexibility and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) are impacted by these reductions in approximately 10 percent of years.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: the median depletion by Mexico is 83.3 percent of allotment, and the 25th to 75th percentiles range from 76.9 to 83.3 percent. Depletions in some outlier years (below the 10th percentile) are affected by dead pool at Lake Mead.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: the median depletion by Mexico is 81.5 percent of allotment, and the 25th to 75th percentiles range from 60.0 to 83.3 percent. Depletions in approximately 25 percent of years are affected by dead pool at Lake Mead.

TA 4.2.6 Issue 5: Lower Division States Combined Shortages

Issue 5 addresses how operational activities affect modeled distribution of combined shortages for the Lower Division States. This will be achieved through the comparison of the various action alternatives to the No Action Alternative and CCS Comparative Baseline for the following metrics:

- Volumes of Shortage by Water User Type (tribal, domestic, irrigation)

As discussed in **Chapter 2**, the alternatives considered evaluate a distribution of shortages via priority and pro rata. Lower Division States' shortage distributions discussed under this issue were modeled with the SAM and ADM to estimate the volume of available water to entitlement holders or water users under Shortage Conditions over a specified range of shortage volumes. There are three unique SAMs and five ADMs to capture the nuances of the alternatives and sensitivity analyses, which are further explained in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation. The following analysis describes the distribution of shortages expected for a specified shortage volume.

Tribal Shortage Impacts

The following **Table TA 4-39** describes shortage impacts on tribal entitlements, broken out by SAM and ADM modeling approach and aligned by alternative. Each row corresponds to a modeling approach and EIS alternative or the CCS Comparative Baseline. Within the row, the color gradient is representative of conditional formatting for values ranging from zero to 1,103 kaf, the total of the entitlements modeled in the tribal category. The color gradient indicates the percentage reduction, with the darkest orange representing 100 percent reduction. The maximum values are a total of the Consumptive Use or equivalent entitlements modeled for tribal users. Each column of modeled total shortage was chosen based on points of interest in one or more models, or to provide granularity in the results over a range of volumes of interest. Total shortage volumes include an assumed component for Mexico, as described in the sections of this appendix pertaining to each model, and will not sum across panels.

As shown in the table, the shortage impacts of priority-based alternatives range from 209-582 kaf. The shortage impacts of pro rata-based alternatives range from 76-378 kaf. The pro rata-based alternatives display smaller shortage impacts compared to the priority-based alternatives at the same total shortage volume considered. For example, under a total shortage volume of 2,100 kaf, the Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives estimate a shortage impact of 510 kaf. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives estimate a shortage impact of 264 and 357 kaf, respectively. Overall, for tribal users, priority-based alternatives result in greater shortage impacts compared to pro rata-based alternatives. These tradeoffs are further discussed in **TA 18**, Indian Trust Assets.

Assuming a maximum shortage volume of 1.5 maf distributed based on the Lower Division States' May 1, 2026 proposal, the Representative Preferred Alternative would impose a maximum shortage of 346 kaf to tribal users in 2027 and 2028,[4] Modeling assumptions for 2029-2060 show a maximum

[4] While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative).

potential impact to tribal users of over 574 kaf, but as demonstrated by the 2027-2028 Operating Guidelines, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative.

Domestic Shortage Impacts

The following **Table TA 4-39** describes shortage impacts on Domestic users, broken out by SAM and ADM modeling approach and aligned by alternative. Each row corresponds to a modeling approach and EIS alternative or the CCS Comparative Baseline. Within the row, the color gradient is representative of conditional formatting for values ranging from zero to 1,606 kaf, the total of the entitlements modeled in the domestic category. The color gradient indicates the percentage reduction, with the darkest orange representing 100 percent reduction. The maximum values are a total of the Consumptive Use or equivalent entitlements modeled for domestic users. Each column of modeled total shortage was chosen based on points of interest in one or more models, or to provide granularity in the results over a range of volumes of interest. Total shortage volumes include an assumed component for Mexico, as described in the sections of this appendix pertaining to each model, and will not sum across panels.

As shown in the table, the shortage impacts of priority-based alternatives range from 277-1,501 kaf. The shortage impacts of pro rata-based alternatives range from 109-546 kaf. The pro rata-based alternatives display smaller shortage impacts compared to the priority-based alternatives at the same total shortage volume considered. For example, under a total shortage volume of 2,100 kaf, the Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives estimate a shortage impact of 1,179 kaf. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives estimate a shortage impact of 382 and 449 kaf, respectively. Overall, for domestic users, priority-based alternatives result in greater shortage impacts compared to pro rata-based alternatives. These tradeoffs are further discussed in **TA 17**, Population and Land Use.

Assuming a maximum shortage volume of 1.5 maf distributed based on the Lower Division States' May 1, 2026 proposal, the Representative Preferred Alternative would impose a maximum shortage of 858 kaf to domestic users in 2027 and 2028[5]. Modeling assumptions for 2029-2060 show a maximum potential impact to domestic users of over 1,472 kaf, but as demonstrated by the 2027-2028 Operating Guidelines, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative.

Irrigation Shortage Impacts

The following **Table TA 4-39** describes shortage impacts on non-tribal irrigation users, broken out by SAM and ADM modeling approach and aligned by alternative. Each row corresponds to a modeling approach and EIS alternative or the CCS Comparative Baseline. Within the row, the color gradient is representative of conditional formatting for values ranging from zero to 4,749 kaf, the total of the entitlements modeled in the irrigation category. The color gradient indicates the

[5] While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative).

Table TA 4-39
Total Shortage Impact Volumes (kaf)

Tribal Shortage Impacts

Modeling Approach	EIS Alternatives and Comparative Baseline	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000
Priority	No Action	241									
Priority	Basic Coordination	241	351	489							
Priority	Representative Preferred Alternative (2029-2060)	241	351	489	550	551	552	555	567	576	
Continuing Current Strategies*	CCS Comparative Baseline	261	305								
LB Priority	Supply Driven (LB Priority approach)	209	269	346	431	483	510				
LB Priority	Maximum Operational Flexibility	209	269	346	431	483	510	550	561	571	582
LB Priority	Representative Preferred Alternative (2027-2028)	209	269	346							
Pro Rata	Enhanced Coordination	76	126	189	227	252	264	289	378		
LB Pro Rata	Supply Driven (LB Pro Rata Approach)	139	207	291	324	346	357				

Domestic Shortage Impacts

Modeling Approach	EIS Alternatives and Comparative Baseline	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000
Priority	No Action	277									
Priority	Basic Coordination	277	488	752							
Priority	Representative Preferred Alternative (2029-2060)	277	488	752	876	1,032	1,102	1,224	1,425	1,472	
Continuing Current Strategies*	CCS Comparative Baseline	297	563								
LB Priority	Supply Driven (LB Priority approach)	313	579	858	1,024	1,125	1,179				

Domestic Shortage Impacts

Modeling Approach	EIS Alternatives and Comparative Baseline	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000
LB Priority	Maximum Operational Flexibility	313	579	858	1,024	1,125	1,179	1,263	1,390	1,446	1,501
LB Priority	Representative Preferred Alternative (2027-2028)	313	579	858							
Pro Rata	Enhanced Coordination	109	182	273	327	364	382	418	546		
LB Pro Rata	Supply Driven (LB Pro Rata approach)	155	240	346	397	432	449				

Irrigation Shortage Impacts

Modeling Approach	EIS Alternatives and Comparative Baseline	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,500	4,000
Priority	No Action	6									
Priority	Basic Coordination	6	19	34							
Priority	Representative Preferred Alternative (2029 -2060)	6	19	34	44	44	56	98	467	829	
Continuing Current Strategies*	CCS Comparative Baseline	8	27								
LB Priority	Supply Driven (LB Priority approach)	2	9	70	79	85	88				
LB Priority	Maximum Operational Flexibility	2	9	70	79	85	88	95	509	860	1,211
LB Priority	Representative Preferred Alternative (2027-2028)	2	9	70							
Pro Rata	Enhanced Coordination	316	526	789	947	1,052	1,105	1,210	1,578		
LB Pro Rata	Supply Driven (LB Pro Rata approach)	206	387	613	778	889	944				

Note:
Totals include Mexico and will not sum across panels.
*CCS Comparative Baseline strategies results are of limited comparability due to their fixed shortage volumes; shortages shown for 600 kafy and 1.0 maf per year in total shortage are associated with 613 kafy and 1,013 kafy of total shortage in the CCS Comparative Baseline SAM.

percentage reduction, with the darkest orange representing 100 percent reduction. The maximum values are a total of the Consumptive Use or equivalent entitlements assigned to irrigation users. Each column of total modeled shortage was chosen based on points of interest in one or more models, or to provide granularity in the results over a range of volumes of interest. Total shortage volumes include an assumed component for Mexico, as described in the sections of this appendix pertaining to each model, and will not sum across panels.

As shown in the table, the shortage impacts of priority-based alternatives range from 2-1,211 kaf. The shortage impacts of pro rata-based alternatives range from 206 to 1,578 kaf. The pro rata-based alternatives display larger shortage impacts compared to the priority-based alternatives at the same total shortage volume considered. For example, under a total shortage volume of 2,100 kaf, the Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives estimate a shortage impact of 88 kaf. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives estimate a shortage impact of 1,105 and 944 kaf, respectively. Overall, for non-tribal irrigation users, pro rata-based alternatives result in greater shortage impacts compared to priority-based alternatives. These tradeoffs are further discussed in **TA 17**, Population and Land Use.

Assuming a maximum shortage volume of 1.5 maf distributed based on the Lower Division States' May 1, 2026 proposal, the Representative Preferred Alternative would impose a maximum shortage of 70 kaf to non-tribal irrigation users in 2027 and 2028[6]. Modeling assumptions for 2029-2060 show a maximum potential impact to non-tribal irrigation users of over 829 kaf, but as demonstrated by the 2027-2028 Operating Guidelines, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative.

Volumes of Shortage by State (Arizona, California, Nevada)

State specific distribution of shortages can be viewed in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

TA 4.2.7 Issue 6: Upper Basin Conservation

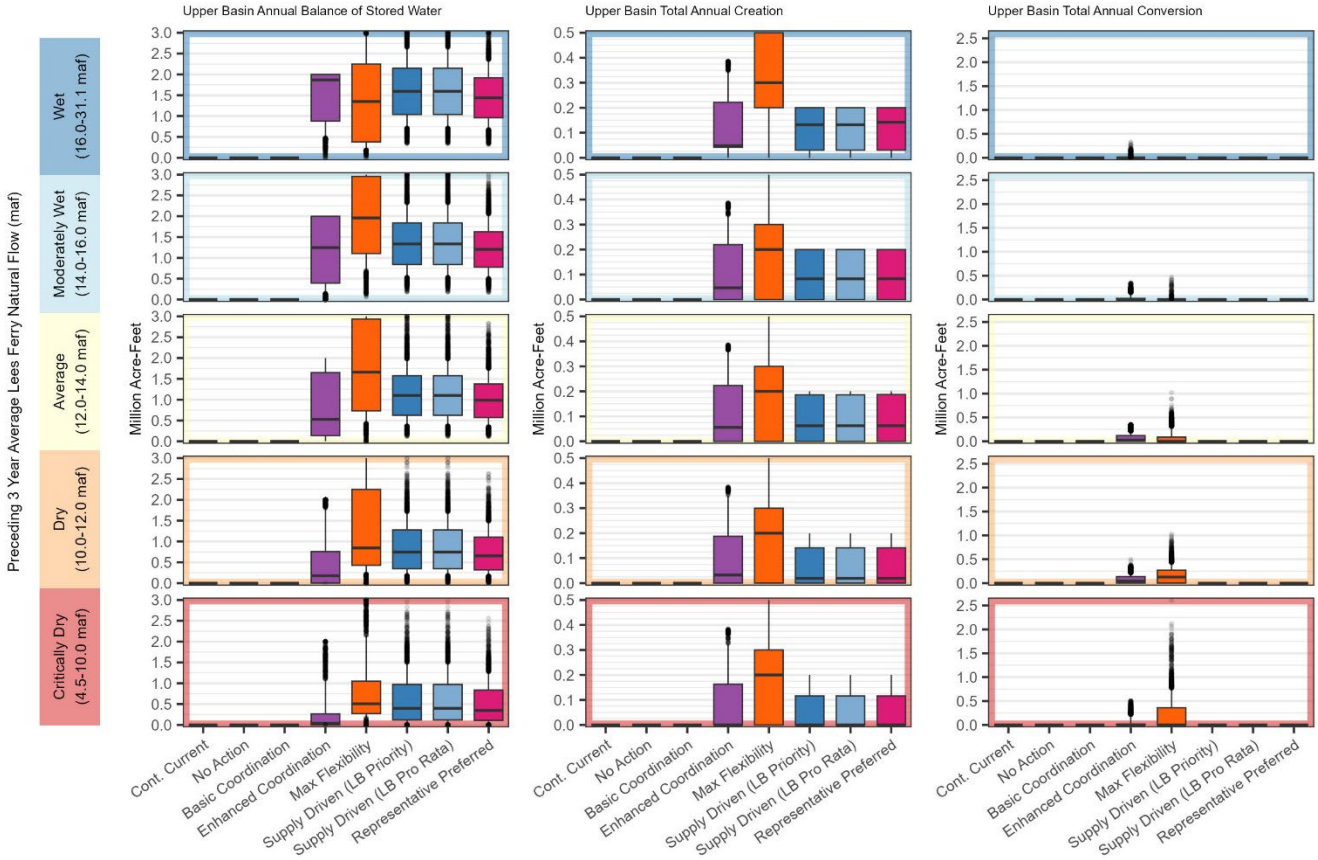
Figure TA 4-19 shows three components of Upper Basin Conservation activity.[7] The first column shows the annual, total volume of conserved water accumulated by the Upper Basin. The second column reports the annual volume of conserved water that is created. The third column reports the annual volume that is converted to system water. Statistical summaries of the data shown in **Figure TA 4-19** are provided in **Table TA 4-40** through **Table TA 4-42** at the end of this technical appendix.

There is zero accumulation, creation, or conversion under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, so the remainder of the discussion on **Figure TA**

[6] While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative).
[7] For all alternatives except Maximum Operational Flexibility, Lower Basin conserved water is stored in Lake Powell. For Maximum Operational Flexibility, this water can be stored in Lake Mead, Lake Powell, or both.

4-19 focuses on Enhanced Coordination, Maximum Operational Flexibility, Representative Preferred, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.[8]

Figure TA 4-19
Annual Upper Basin Conservation Activity



Note: In addition to the conservation volumes, the Supply Driven alternative also includes "gap water" (see EIS **Appendix S,** Additional Description of Alternatives, and **Appendix A,** CRSS Model Documentation). The modeled gap water volume increases with higher natural flow release percentages and drier hydrologic conditions. The median is 0.0 maf for the 60 and 65 percent natural flow release scenarios in the Average and Critically Dry flow categories, and increases to slightly over 0.1 maf and 0.8 maf, respectively, for the 70 percent scenario; the maximum gap water volume across all flow categories is approximately 1.1 maf. **Appendix D**, Sensitivity Analysis – Effects of Natural Flow Percentage Used for the Supply Driven Alternative, includes additional information on the modeled volumes of gap water.

Considering total annual accumulation (first column), in the Average Flow Category, the Maximum Operational Flexibility Alternative has the highest median (1.7 maf), followed by the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches; 1.1 maf) and the Representative Preferred and the Enhanced Coordination Alternatives (1.0 maf and 0.5 maf, respectively). The relative ranking is the same under the Critically Dry Flow Category, with medians of 0.5 maf

[8] UB conservation activity is the same for both the LB Priority and LB Pro Rata approaches under the Supply Driven Alternative.

(Maximum Operational Flexibility Alternative), 0.4 maf (Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]), 0.3 maf (Representative Preferred Alternative), and 0.0 maf (Enhanced Coordination Alternative).

Considering total annual creation (second column), under the Average Flow Category, the Maximum Operational Flexibility Alternative has the largest median (0.2 maf), followed by the Representative Preferred, Supply Driven (both LB Priority and LB Pro Rata approaches), and Enhanced Coordination Alternatives at around 0.1 maf. Under the Critically Dry Flow Category, the median for the Maximum Operational Flexibility Alternative remains at 0.2 maf, but the median is 0.0 maf for the Enhanced Coordination, Representative Preferred, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. However, the 75th percentiles are 0.3 maf (Maximum Operational Flexibility Alternative), 0.2 maf (Enhanced Coordination Alternative), and 0.1 maf (Representative Preferred and Supply Driven [both LB Priority and LB Pro Rata approaches] Alternatives).

Considering total annual conversion (third column), the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) does not convert any conserved water since conservation is created as system water (i.e., values of 0.0 maf for all flow categories and all percentiles). For the Maximum Operational Flexibility and Enhanced Coordination Alternatives, the largest conversion volumes occur in Dry to Critically Dry Flow Categories. Because conversion happens relatively infrequently and at small volumes, it is useful to compare the 75th percentile values. In the Dry Flow Category, 75th percentile conversion volumes are 0.3 maf (Maximum Operational Flexibility Alternative) and 0.1 maf (Enhanced Coordination Alternative). Under the Critically Dry Flow Category, the 75th percentile values are 0.4 maf (Maximum Operational Flexibility Alternative) and approximately 0.0 maf (Enhanced Coordination Alternative).

TA 4.2.8 Issue 7: Lower Division States' 2027-2028 Water Supply Determinations in the Representative Preferred Alternative

The Preferred Alternative is a decision framework under which specific operating guidelines will be periodically reviewed, developed, and updated. Within the framework, the specific shortage volumes and distributions within the operational sideboards will be determined for each set of guidelines. As described in **Chapter 2**, the Representative Preferred Alternative was designed to capture these operational sideboards, but the volume and distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ.

As of the date of this Final EIS, the first set of operating guidelines are anticipated to cover 2027-2028. To reflect the May 1, 2026 proposal by the Lower Division States, the Representative Preferred Alternative used the LB Priority distribution method for 2027 and 2028, up to 1.5 maf of shortage, as noted in the description of the alternative. The figures below show impacts in 2027 and 2028 of the Representative Preferred Alternative modeling.

While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet to determine potential additional reductions to Lower Basin water deliveries.

Figure TA 4-20, shows the occurrences of different volumes of total annual Lower Basin shortage volumes modeled in the Representative Preferred Alternative in the years 2027 and 2028 across the 400 modeled traces. In 2027, all 400 traces resulted in a 1.5-maf shortage. In 2028, only 148 traces resulted in a 1.5 maf shortage, while 252 traces resulted in larger shortage volumes, up to 3 maf occurring in 3 traces. Because shortages greater than 1.5 maf are subject to consultation, as is their distribution should they be deemed necessary, they will not be further analyzed.

Figure TA 4-20
Distribution of 2027-2028 Total Annual Lower Basin Shortage Volumes in the Representative Preferred Alternative

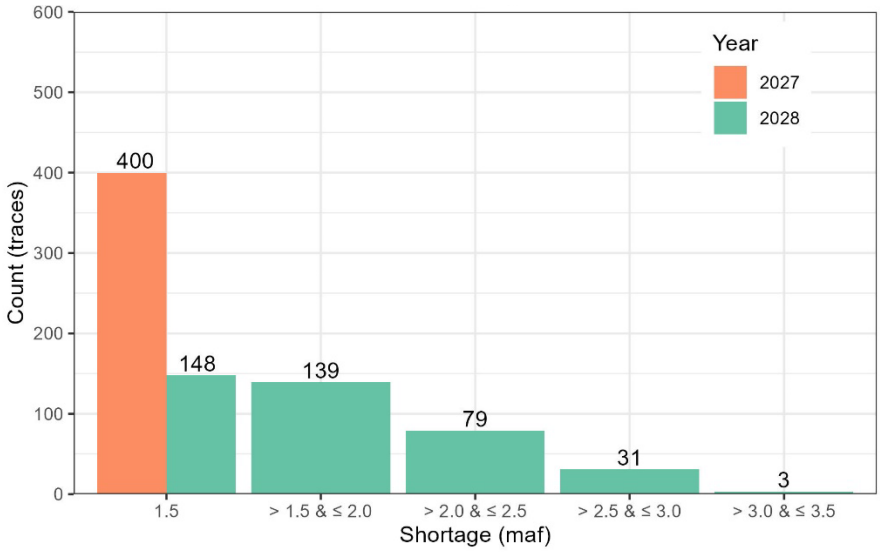


Figure TA 4-21, shows the distribution of annual depletions for each state in 2027 and 2028 in the Representative Preferred Alternative. The panel for each state is scaled by its apportionment; the left vertical axis for each panel shows depletions by percent of apportionment, and the right vertical axis shows absolute volumes of depletions. Arizona's median 2027-2028 depletion is 58.5 percent of apportionment, or 1.6 maf, with maximum and minimum depletions of 75.3 percent and 56.6 percent. California's median 2027-2028 depletion is 89.2 percent of apportionment, or 3.9 maf, with maximum and minimum depletions of 99.8 percent and 78.9 percent. Nevada's median 2027-2028 depletion is 73.3 percent of apportionment, or 0.2 maf, with maximum and minimum depletions of 86.0 percent and 73.3 percent. These modeled depletions reflect the assumed shortage distribution method, as well as the assumptions for the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water, for detailed assumptions). **Table TA 4-43** provides the statistical summary of data in **Figure TA 4-21**.

Figure TA 4-21
Distribution of 2027-2028 Annual Depletions by State in the Representative Preferred Alternative

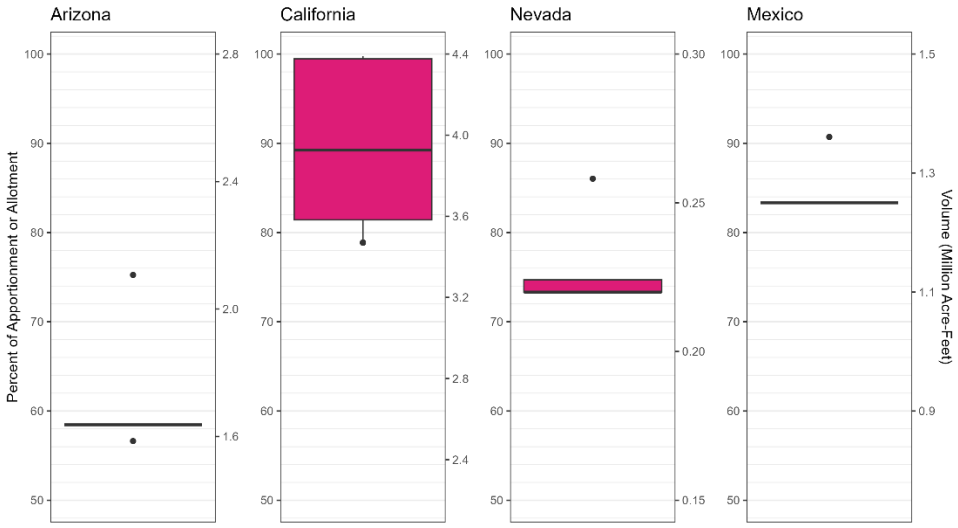


Table TA 4-43
Distribution of 2027-2028 Annual Depletions by State in the Representative Preferred Alternative

State	Max		90th Percentile		75th Percentile		50th Percentile		25th Percentile		10th Percentile		Min	
	%	maf	%	maf	%	maf	%	maf	%	maf	%	maf	%	maf
Arizona	75.3	2.1	58.5	1.6	58.5	1.6	58.5	1.6	58.5	1.6	58.5	1.6	56.6	1.6
California	99.8	4.4	99.8	4.4	99.5	4.4	89.2	3.9	81.4	3.6	78.9	3.5	78.9	3.5
Nevada	86.0	0.3	74.7	0.2	74.7	0.2	73.3	0.2	73.3	0.2	73.3	0.2	73.3	0.2
Mexico	90.7	1.4	83.3	1.3	83.3	1.3	83.3	1.3	83.3	1.3	83.3	1.3	83.3	1.3

TA 4.2.9 Summary Comparison of Alternatives

Summary of Issue 1: Apportionments to the Upper Division States

Issue 1 considered whether the alternatives could affect apportionments to the Upper Division States. Because no changes to those apportionments are expected, no further impact analysis was needed.

Summary of Issue 2: Lower Division States' Apportionments and Water Entitlements

Issue 2 considered whether the alternatives could affect the Lower Division States' apportionments or water entitlements. The shortage distribution approaches were evaluated to explore potential concepts and impacts and not to change existing apportionments or entitlements. Related delivery effects are addressed under Issues 3, 5 and 7, and further summarized below.

Summary of Issue 3: Lower Division States Water Supply Determinations

Issue 3 evaluates how the operational alternatives would affect water supplies for the Lower Division States and Mexico, including shortages, dead pool-related reductions, conservation activity, depletions, delivery reductions, and surplus deliveries. The results show a recurring tradeoff where alternatives with lower planned shortages tend to leave Lake Mead more vulnerable, increasing the risk of dead pool-related reductions. Alternatives with larger or more responsive shortages tend to provide stronger protection against dead pool-related reductions by increasing reservoir elevations and reducing the frequency and magnitude of unplanned cuts. This pattern is most apparent in the No Action and Basic Coordination Alternatives, which have lower planned shortages but show greater dead pool risk than the other action alternatives.

Differences among the operational alternatives become more pronounced as hydrology becomes drier. Most action alternatives include mechanisms for storing and delivering conserved water in Lake Powell and Lake Mead, with the Basic Coordination Alternative as the exception. Modeled conservation activity generally does not substantially change median Lower Basin shortages, dead pool-related reductions, or depletions in most cases, but it can significantly affect the ranges of these outcomes, especially in the Average Flow Category. As conditions become drier, annual conservation creation decreases, causing stored-water balances to decline. In Critically Dry conditions, delivery and conversion can also be limited by lower available stored water or low Lake Mead elevations.

Impacts also vary by how shortages are distributed. Arizona, Nevada, and Mexico tend to see median shortages increase as conditions become drier. California's outcomes depend more on how shortages are distributed, with priority-based approaches limiting or avoiding reductions and pro rata approaches spreading reductions to a broader set of users, including senior priority groups. Depletions reflect the combined effects of shortage volume, shortage distribution, conservation assumptions, and dead pool-related constraints. In the driest conditions, depletions tend to decline as shortages increase and access to conserved water becomes more limited. Overall, surplus deliveries occur infrequently and are concentrated in less severe hydrologic categories.

The Representative Preferred Alternative uses planned shortages to provide stronger protection against dead pool-related reductions. Under both Dry and Critically Dry conditions, the median Lower Basin shortage increases from 1.5 maf in Dry conditions to 2.1 maf in Critically Dry conditions, while median dead pool-related reductions remain 0.0 maf. Dead pool-related reductions are limited to outlier years in the Dry Flow Category, with a maximum of 1.4 maf, whereas in the Critically Dry category they occur in about 10 percent of years and reach a maximum of 3.8 maf. The vulnerability analysis shows that the Representative Preferred Alternative would likely become vulnerable to at least one dead pool-related reduction only under a 10-year average Lees Ferry annual flow of 8.0 maf, a condition much drier than the observed record and present in fewer than 10 percent of Drying with Variability traces. At the state and Mexico level, shortages and delivery reductions under the Representative Preferred Alternative increase for Arizona, Nevada, and Mexico as conditions become Dry and Critically Dry, while California has a median shortage of 0.0 percent in Dry conditions and 10.0 percent in Critically Dry conditions. Depletions under the Representative Preferred Alternative generally decline in Critically Dry conditions as shortage volumes increase and dead pool-related reductions are implemented in some years.

Summary of Issue 4: Deliveries to Mexico

Issue 4 evaluates how the alternatives would affect Colorado River deliveries to Mexico, using two metrics: annual water delivery reductions to Mexico and annual depletions in Mexico. In the Average Flow Category, Mexico's median depletions range from 93.3 percent of allotment under the No Action Alternative to 78.5 percent under the Maximum Operational Flexibility Alternative, and Mexico generally receives its full allotment in about 10 percent of years or fewer. In this same flow category, dead pool-related reductions at Lake Mead occur frequently under the No Action and Basic Coordination Alternatives, but are limited or absent under several other alternatives.

For the Representative Preferred Alternative, Mexico's median depletions are relatively similar between the Dry and Critically Dry flow categories, but variability and dead pool effects increase under the driest conditions. In the Dry Flow Category, Mexico's median depletion is 83.3 percent of allotment, while the median depletion is 81.5 percent in the Critically Dry Flow Category. Under this alternative, dead pool-related reductions affect approximately 25 percent of Critically Dry years, which is less frequent than under No Action but more common than under Maximum Operational Flexibility and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

Summary of Issue 5: Lower Division States' Combined Shortages

Issue 5 evaluates how operational activities under the action alternatives would affect the modeled distribution of combined shortages among Lower Division States water users, compared to the No Action Alternative and CCS Comparative Baseline. The analysis focuses on shortage volumes by water user type (tribal, domestic, and non-tribal irrigation) and uses the SAM and ADM to estimate how available water could be reduced under a range of shortage conditions. Across the alternatives, shortage outcomes vary depending on whether reductions are distributed primarily by priority or on a pro rata basis, with the modeling results illustrating how these different distribution approaches shift impacts among user groups.

In general, priority-based approaches tend to result in greater modeled shortages for tribal and domestic users, while pro rata-based approaches tend to distribute larger shortage impacts to non-tribal irrigation users. This reflects a tradeoff among alternatives, where approaches that protect certain users based on priority may concentrate shortages among other entitlement holders, while broader pro rata approaches spread reductions more evenly but can increase impacts to irrigation users. Under the Representative Preferred Alternative, maximum modeled shortages in 2027 and 2028 would be 346 kaf for tribal users, 858 kaf for domestic users, and 70 kaf for non-tribal irrigation users, unless critical Lake Mead elevations prompt consultation and consideration of additional volumes. For 2029 through 2060, modeling shows the potential for larger impacts, but the actual distribution of shortages would depend on the specific operating guidelines adopted under the Preferred Alternative decision framework.

Summary of Issue 6: Upper Basin Conservation

Upper Basin conservation activity occurs only under the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives. There is no accumulation, creation, or conversion under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives. In general, annual accumulation is highest under Maximum Operational Flexibility, followed by the Supply

Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives. Annual creation is also highest under Maximum Operational Flexibility, while the other alternatives generally create smaller volumes and show more limited creation, particularly in the Critically Dry Flow Category. Conversion of conserved water is more limited overall, and the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives do not show conversion because, for the former, conserved water is created directly as system water, and for the latter, there is no conversion mechanism assumed in the modeling.

Summary of Issue 7: Lower Division States' 2027-2028 Water Supply Determinations in the Representative Preferred Alternative

The Preferred Alternative establishes a decision framework rather than a single fixed set of operating rules. Under that framework, specific operating guidelines will be developed and adopted periodically, and the actual shortage volumes and distributions may differ from those modeled in the Representative Preferred Alternative. The Lower Division States' proposal for distributing shortages up to 1.5 maf on May 1, 2026 was incorporated in the Representative Preferred Alternative for 2027 and 2028.

In the Representative Preferred Alternative modeling, all 400 traces show a 1.5-maf Lower Basin shortage in 2027. In 2028, 148 traces remain at 1.5 maf, while 252 traces show larger shortages, with up to 3.0 maf in 3 traces. It is anticipated that volumes and distribution of shortages above 1.5 maf, should they be deemed necessary, would be developed based on consultation and are not analyzed in this Issue. Modeled 2027-2028 depletions reflect the assumed shortage distribution method and conserved-water assumptions, with median depletions of about 1.6 maf for Arizona, 3.9 maf for California, 0.2 maf for Nevada, and 1.3 maf for Mexico.

TA 4.3 Statistical Summary Tables

Table TA 4-10
Lower Basin Shortage (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	1.4	0.7	0.6	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	1.4	1.4	1.0	0.6	0.0	0.0	0.0
CCS Comparative Baseline	12-14	1.4	1.4	1.4	1.1	0.6	0.0	0.0
CCS Comparative Baseline	10-12	1.4	1.4	1.4	1.4	1.1	0.2	0.0
CCS Comparative Baseline	< 10	1.4	1.4	1.4	1.4	1.1	1.0	0.0
No Action	> 16	0.6	0.6	0.6	0.0	0.0	0.0	0.0
No Action	14-16	0.6	0.6	0.6	0.6	0.0	0.0	0.0
No Action	12-14	0.6	0.6	0.6	0.6	0.5	0.0	0.0
No Action	10-12	0.6	0.6	0.6	0.6	0.6	0.4	0.0
No Action	< 10	0.6	0.6	0.6	0.6	0.6	0.5	0.0
Basic Coordination	> 16	1.5	1.5	1.5	0.0	0.0	0.0	0.0
Basic Coordination	14-16	1.5	1.5	1.5	1.5	0.0	0.0	0.0
Basic Coordination	12-14	1.5	1.5	1.5	1.5	1.1	0.0	0.0
Basic Coordination	10-12	1.5	1.5	1.5	1.5	1.5	0.8	0.0
Basic Coordination	< 10	1.5	1.5	1.5	1.5	1.5	1.4	0.0
Enhanced Coordination	> 16	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	3.0	1.8	1.5	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	3.0	2.6	2.1	1.6	0.0	0.0	0.0
Enhanced Coordination	10-12	3.0	3.0	2.9	2.4	1.7	1.4	0.0
Enhanced Coordination	< 10	3.0	3.0	3.0	3.0	2.5	1.9	0.0
Max. Operational Flexibility	> 16	1.9	1.0	0.5	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	2.6	1.7	1.4	0.9	0.3	0.0	0.0
Max. Operational Flexibility	12-14	3.3	2.0	2.0	1.7	1.0	0.4	0.0
Max. Operational Flexibility	10-12	4.0	3.1	2.7	2.0	2.0	1.2	0.0
Max. Operational Flexibility	< 10	4.0	4.0	3.6	3.1	2.5	2.0	0.4
Supply Driven (LB Priority)	> 16	2.1	1.5	1.4	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	2.1	1.9	1.5	0.9	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	2.1	2.1	1.8	1.5	0.2	0.0	0.0
Supply Driven (LB Priority)	10-12	2.1	2.1	2.1	1.8	1.5	0.2	0.0
Supply Driven (LB Priority)	< 10	2.1	2.1	2.1	2.0	1.5	1.5	0.0
Supply Driven (LB Pro Rata)	> 16	2.1	1.5	1.4	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	2.1	1.9	1.5	0.9	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	2.1	2.1	1.8	1.5	0.2	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	2.1	2.1	2.1	1.8	1.5	0.2	0.0
Supply Driven (LB Pro Rata)	< 10	2.1	2.1	2.1	2.0	1.6	1.5	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Representative Preferred	> 16	2.9	1.5	0.3	0.0	0.0	0.0	0.0
Representative Preferred	14-16	3.6	1.5	1.5	0.2	0.0	0.0	0.0
Representative Preferred	12-14	3.6	1.7	1.5	1.5	0.0	0.0	0.0
Representative Preferred	10-12	3.6	3.2	2.2	1.5	1.5	0.0	0.0
Representative Preferred	< 10	3.6	3.6	3.6	2.1	1.5	1.3	0.0

Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-11
Lower Basin Dead Pool–Related Reductions (maf)[9]

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	1.1	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	2.4	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	4.0	1.4	0.4	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	6.2	3.0	2.0	0.2	0.0	0.0	0.0
No Action	> 16	1.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	1.5	0.3	0.0	0.0	0.0	0.0	0.0
No Action	12-14	3.8	0.8	0.3	0.0	0.0	0.0	0.0
No Action	10-12	5.5	2.5	1.5	0.4	0.0	0.0	0.0
No Action	< 10	6.5	4.0	3.1	1.5	0.0	0.0	0.0
Basic Coordination	> 16	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	1.9	0.1	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	4.4	1.1	0.4	0.0	0.0	0.0	0.0
Basic Coordination	< 10	6.1	2.9	1.6	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	10-12	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	< 10	3.9	1.1	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	3.4	0.0	0.0	0.0	0.0	0.0	0.0

[9] Dead pool–related reductions are in addition to shortages specified in each alternative. Shortages are shown in Table TA 4-10.

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	1.7	0.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	4.3	1.5	0.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	4.3	1.2	0.0	0.0	0.0	0.0	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	3.8	0.0	0.0	0.0	0.0	0.0	0.0

Note: Dead pool-related delivery reduction volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-13
Annual Lower Basin Conservation Activity: Lower Basin Annual Balance of Stored Water (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	4.2	4.2	3.9	3.3	2.5	1.1	0.5
CCS Comparative Baseline	14-16	4.2	4.2	4.2	3.8	3.2	2.5	0.6
CCS Comparative Baseline	12-14	4.2	4.2	4.2	4.1	3.5	3.0	0.7
CCS Comparative Baseline	10-12	4.2	4.2	4.2	4.2	3.6	3.1	1.0
CCS Comparative Baseline	< 10	4.2	4.2	4.2	4.2	3.3	3.1	0.9
No Action	> 16	2.7	1.9	0.3	0.3	0.0	0.0	0.0
No Action	14-16	2.7	2.2	0.3	0.3	0.2	0.0	0.0
No Action	12-14	2.7	2.4	1.1	0.3	0.3	0.1	0.0
No Action	10-12	2.7	2.4	1.9	0.3	0.3	0.2	0.0
No Action	< 10	2.7	2.7	2.5	0.3	0.3	0.2	0.0
Basic Coordination	> 16	2.7	1.6	0.3	0.2	0.0	0.0	0.0
Basic Coordination	14-16	2.7	1.9	0.3	0.3	0.1	0.0	0.0
Basic Coordination	12-14	2.7	2.4	0.4	0.3	0.2	0.0	0.0
Basic Coordination	10-12	2.7	2.5	1.4	0.3	0.2	0.1	0.0
Basic Coordination	< 10	2.7	2.7	2.5	0.3	0.3	0.1	0.0
Enhanced Coordination	> 16	7.0	6.0	4.9	3.2	0.2	0.0	0.0
Enhanced Coordination	14-16	7.0	6.5	5.7	4.1	2.5	1.5	0.0
Enhanced Coordination	12-14	7.0	6.4	5.4	3.3	2.3	1.7	0.0
Enhanced Coordination	10-12	7.0	6.0	4.5	2.8	2.1	1.5	0.0
Enhanced Coordination	< 10	7.0	5.2	3.3	2.6	2.1	1.6	0.1
Max. Operational Flexibility	> 16	5.0	5.0	4.3	2.5	0.4	0.2	0.0
Max. Operational Flexibility	14-16	5.0	5.0	5.0	3.3	1.7	0.9	0.0
Max. Operational Flexibility	12-14	5.0	5.0	4.6	2.7	1.4	0.8	0.0
Max. Operational Flexibility	10-12	5.0	5.0	3.6	2.3	1.2	0.7	0.1
Max. Operational Flexibility	< 10	5.4	4.0	3.3	2.7	1.4	0.7	0.0
Supply Driven (LB Priority)	> 16	7.9	5.6	4.3	2.4	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	7.6	6.1	4.9	3.6	2.0	0.8	0.0
Supply Driven (LB Priority)	12-14	7.9	6.2	4.8	3.5	2.2	1.3	0.0
Supply Driven (LB Priority)	10-12	7.9	5.9	4.4	3.0	2.0	1.3	0.0
Supply Driven (LB Priority)	< 10	7.8	5.0	3.7	2.8	1.9	1.2	0.0
Supply Driven (LB Pro Rata)	> 16	7.9	6.4	5.6	4.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	7.7	6.7	6.3	5.3	3.9	1.0	0.0
Supply Driven (LB Pro Rata)	12-14	7.9	6.8	6.3	5.5	4.4	3.2	0.0
Supply Driven (LB Pro Rata)	10-12	7.9	6.7	6.2	5.3	4.1	3.4	0.0
Supply Driven (LB Pro Rata)	< 10	7.8	6.4	5.8	4.6	3.6	3.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Representative Preferred	> 16	8.0	5.3	4.5	3.5	0.0	0.0	0.0
Representative Preferred	14-16	8.0	6.3	4.9	4.1	3.3	1.3	0.0
Representative Preferred	12-14	8.0	6.3	4.8	4.0	3.4	2.7	0.0
Representative Preferred	10-12	8.0	6.1	4.5	3.8	3.3	2.8	0.0
Representative Preferred	< 10	8.0	4.9	4.3	3.7	3.3	2.9	0.2

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-14
Annual Lower Basin Conservation Activity: Lower Basin Total Annual Creation (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.6	0.3	0.1	0.1	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.6	0.4	0.3	0.1	0.1	0.0	0.0
CCS Comparative Baseline	12-14	0.6	0.4	0.4	0.3	0.1	0.1	0.0
CCS Comparative Baseline	10-12	0.7	0.4	0.4	0.4	0.2	0.1	0.0
CCS Comparative Baseline	< 10	0.7	0.5	0.4	0.4	0.2	0.2	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	1.7	0.9	0.9	0.5	0.2	0.2	0.1
Enhanced Coordination	14-16	1.7	1.0	0.7	0.5	0.3	0.2	0.1
Enhanced Coordination	12-14	1.7	0.8	0.5	0.4	0.2	0.1	0.0
Enhanced Coordination	10-12	1.7	0.6	0.4	0.3	0.1	0.1	0.0
Enhanced Coordination	< 10	1.5	0.4	0.3	0.1	0.1	0.0	0.0
Max. Operational Flexibility	> 16	2.1	1.3	0.9	0.5	0.1	0.1	0.0
Max. Operational Flexibility	14-16	2.1	1.2	0.9	0.5	0.2	0.1	0.0
Max. Operational Flexibility	12-14	2.1	1.0	0.8	0.4	0.1	0.1	0.0
Max. Operational Flexibility	10-12	1.9	0.9	0.7	0.2	0.1	0.0	0.0
Max. Operational Flexibility	< 10	1.7	0.7	0.4	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Priority)	> 16	2.2	1.0	0.9	0.5	0.1	0.1	0.0
Supply Driven (LB Priority)	14-16	2.0	0.9	0.7	0.5	0.1	0.1	0.0
Supply Driven (LB Priority)	12-14	2.0	0.9	0.6	0.4	0.1	0.0	0.0
Supply Driven (LB Priority)	10-12	2.0	0.7	0.5	0.3	0.1	0.0	0.0
Supply Driven (LB Priority)	< 10	2.0	0.7	0.5	0.2	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	2.2	0.9	0.8	0.5	0.1	0.1	0.0
Supply Driven (LB Pro Rata)	14-16	1.7	0.9	0.7	0.4	0.1	0.1	0.0
Supply Driven (LB Pro Rata)	12-14	2.0	0.9	0.6	0.3	0.2	0.1	0.0
Supply Driven (LB Pro Rata)	10-12	1.9	0.8	0.6	0.3	0.2	0.1	0.0
Supply Driven (LB Pro Rata)	< 10	1.9	0.8	0.6	0.3	0.1	0.0	0.0
Representative Preferred	> 16	2.1	1.1	0.8	0.2	0.2	0.1	0.1
Representative Preferred	14-16	1.8	1.1	0.6	0.2	0.1	0.1	0.1
Representative Preferred	12-14	1.9	1.0	0.6	0.2	0.1	0.1	0.0
Representative Preferred	10-12	2.1	0.9	0.5	0.2	0.1	0.1	0.0
Representative Preferred	< 10	2.0	0.9	0.5	0.2	0.1	0.1	0.0

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-15
Annual Lower Basin Conservation Activity: Lower Basin Total Annual Delivery and Conversion (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.5	0.2	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.4	0.1	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.3	0.1	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.3	0.1	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.3	0.1	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.7	0.1	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.6	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.6	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.6	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.6	0.3	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.6	0.2	0.1	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.6	0.2	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.7	0.1	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.6	0.3	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Enhanced Coordination	> 16	0.6	0.1	0.1	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.8	0.3	0.2	0.1	0.0	0.0	0.0
Enhanced Coordination	12-14	0.8	0.4	0.3	0.1	0.0	0.0	0.0
Enhanced Coordination	10-12	1.0	0.4	0.3	0.1	0.0	0.0	0.0
Enhanced Coordination	< 10	0.9	0.5	0.4	0.0	0.0	0.0	0.0
Max. Operational Flexibility	> 16	0.7	0.3	0.1	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.7	0.4	0.3	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	1.0	0.5	0.3	0.1	0.0	0.0	0.0
Max. Operational Flexibility	10-12	1.2	0.6	0.4	0.2	0.0	0.0	0.0
Max. Operational Flexibility	< 10	1.9	0.7	0.4	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	1.0	0.3	0.1	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	1.3	0.4	0.3	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	1.3	0.6	0.3	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	1.3	0.5	0.3	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	1.3	0.5	0.3	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	0.6	0.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.7	0.3	0.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.7	0.3	0.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	0.7	0.3	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	0.7	0.3	0.2	0.1	0.0	0.0	0.0
Representative Preferred	> 16	1.2	0.3	0.1	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.8	0.4	0.1	0.1	0.0	0.0	0.0
Representative Preferred	12-14	1.3	0.5	0.2	0.1	0.0	0.0	0.0
Representative Preferred	10-12	0.9	0.5	0.3	0.1	0.0	0.0	0.0
Representative Preferred	< 10	0.8	0.5	0.1	0.0	0.0	0.0	0.0

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-16
Effects of Conservation Activity Modeling Assumptions on Lower Basin Shortage (maf)

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
CCS Comparative Baseline	On	> 16	1.4	0.7	0.6	0.0	0.0	0.0	0.0
CCS Comparative Baseline	Off	> 16	1.4	0.6	0.6	0.0	0.0	0.0	0.0
CCS Comparative Baseline	On	14-16	1.4	1.4	1.0	0.6	0.0	0.0	0.0
CCS Comparative Baseline	Off	14-16	1.4	1.2	1.0	0.6	0.0	0.0	0.0
CCS Comparative Baseline	On	12-14	1.4	1.4	1.4	1.1	0.6	0.0	0.0
CCS Comparative Baseline	Off	12-14	1.4	1.4	1.4	1.0	0.5	0.0	0.0
CCS Comparative Baseline	On	10-12	1.4	1.4	1.4	1.4	1.1	0.2	0.0
CCS Comparative Baseline	Off	10-12	1.4	1.4	1.4	1.4	1.0	0.2	0.0
CCS Comparative Baseline	On	< 10	1.4	1.4	1.4	1.4	1.1	1.0	0.0
CCS Comparative Baseline	Off	< 10	1.4	1.4	1.4	1.4	1.1	0.7	0.0
No Action	On	> 16	0.6	0.6	0.6	0.0	0.0	0.0	0.0
No Action	Off	> 16	0.6	0.6	0.5	0.0	0.0	0.0	0.0
No Action	On	14-16	0.6	0.6	0.6	0.6	0.0	0.0	0.0
No Action	Off	14-16	0.6	0.6	0.6	0.6	0.0	0.0	0.0
No Action	On	12-14	0.6	0.6	0.6	0.6	0.5	0.0	0.0
No Action	Off	12-14	0.6	0.6	0.6	0.6	0.5	0.0	0.0
No Action	On	10-12	0.6	0.6	0.6	0.6	0.6	0.4	0.0
No Action	Off	10-12	0.6	0.6	0.6	0.6	0.6	0.4	0.0
No Action	On	< 10	0.6	0.6	0.6	0.6	0.6	0.5	0.0
No Action	Off	< 10	0.6	0.6	0.6	0.6	0.6	0.5	0.0
Basic Coordination	On	> 16	1.5	1.5	1.5	0.0	0.0	0.0	0.0
Basic Coordination	Off	> 16	1.5	1.5	1.5	0.0	0.0	0.0	0.0
Basic Coordination	On	14-16	1.5	1.5	1.5	1.5	0.0	0.0	0.0
Basic Coordination	Off	14-16	1.5	1.5	1.5	1.3	0.0	0.0	0.0
Basic Coordination	On	12-14	1.5	1.5	1.5	1.5	1.1	0.0	0.0
Basic Coordination	Off	12-14	1.5	1.5	1.5	1.5	1.0	0.0	0.0
Basic Coordination	On	10-12	1.5	1.5	1.5	1.5	1.5	0.8	0.0
Basic Coordination	Off	10-12	1.5	1.5	1.5	1.5	1.5	0.7	0.0
Basic Coordination	On	< 10	1.5	1.5	1.5	1.5	1.5	1.4	0.0
Basic Coordination	Off	< 10	1.5	1.5	1.5	1.5	1.5	1.3	0.0
Enhanced Coordination	On	> 16	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	> 16	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	On	14-16	3.0	1.8	1.5	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	14-16	3.0	2.1	1.7	0.0	0.0	0.0	0.0
Enhanced Coordination	On	12-14	3.0	2.6	2.1	1.6	0.0	0.0	0.0
Enhanced Coordination	Off	12-14	3.0	2.8	2.4	1.8	1.4	0.0	0.0
Enhanced Coordination	On	10-12	3.0	3.0	2.9	2.4	1.7	1.4	0.0

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
Enhanced Coordination	Off	10-12	3.0	3.0	3.0	2.6	2.0	1.6	0.0
Enhanced Coordination	On	< 10	3.0	3.0	3.0	3.0	2.5	1.9	0.0
Enhanced Coordination	Off	< 10	3.0	3.0	3.0	3.0	2.8	2.2	0.0
Max. Operational Flexibility	On	> 16	1.9	1.0	0.5	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	> 16	1.8	0.9	0.4	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	14-16	2.6	1.7	1.4	0.9	0.3	0.0	0.0
Max. Operational Flexibility	Off	14-16	2.5	1.6	1.3	0.8	0.1	0.0	0.0
Max. Operational Flexibility	On	12-14	3.3	2.0	2.0	1.7	1.0	0.4	0.0
Max. Operational Flexibility	Off	12-14	3.2	2.3	2.0	1.6	0.9	0.3	0.0
Max. Operational Flexibility	On	10-12	4.0	3.1	2.7	2.0	2.0	1.2	0.0
Max. Operational Flexibility	Off	10-12	3.8	3.1	2.8	2.4	1.9	1.1	0.0
Max. Operational Flexibility	On	< 10	4.0	4.0	3.6	3.1	2.5	2.0	0.4
Max. Operational Flexibility	Off	< 10	4.0	3.9	3.6	3.1	2.6	2.3	0.3
Supply Driven (LB Priority)	On	> 16	2.1	1.5	1.4	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	> 16	2.1	1.5	0.9	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	14-16	2.1	1.9	1.5	0.9	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	14-16	2.1	1.7	1.5	0.5	0.0	0.0	0.0
Supply Driven (LB Priority)	On	12-14	2.1	2.1	1.8	1.5	0.2	0.0	0.0
Supply Driven (LB Priority)	Off	12-14	2.1	2.1	1.7	1.5	0.0	0.0	0.0
Supply Driven (LB Priority)	On	10-12	2.1	2.1	2.1	1.8	1.5	0.2	0.0
Supply Driven (LB Priority)	Off	10-12	2.1	2.1	2.1	1.6	1.5	0.0	0.0
Supply Driven (LB Priority)	On	< 10	2.1	2.1	2.1	2.0	1.5	1.5	0.0
Supply Driven (LB Priority)	Off	< 10	2.1	2.1	2.1	1.9	1.5	1.5	0.0
Supply Driven (LB Pro Rata)	On	> 16	2.1	1.5	1.4	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	> 16	2.1	1.5	0.9	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	14-16	2.1	1.9	1.5	0.9	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	14-16	2.1	1.7	1.5	0.5	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	12-14	2.1	2.1	1.8	1.5	0.2	0.0	0.0
Supply Driven (LB Pro Rata)	Off	12-14	2.1	2.1	1.7	1.5	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	10-12	2.1	2.1	2.1	1.8	1.5	0.2	0.0
Supply Driven (LB Pro Rata)	Off	10-12	2.1	2.1	2.1	1.6	1.5	0.0	0.0
Supply Driven (LB Pro Rata)	On	< 10	2.1	2.1	2.1	2.0	1.6	1.5	0.0
Supply Driven (LB Pro Rata)	Off	< 10	2.1	2.1	2.1	1.9	1.5	1.5	0.0
Representative Preferred	On	> 16	2.9	1.5	0.3	0.0	0.0	0.0	0.0
Representative Preferred	Off	> 16	3.3	1.5	1.4	0.0	0.0	0.0	0.0
Representative Preferred	On	14-16	3.6	1.5	1.5	0.2	0.0	0.0	0.0
Representative Preferred	Off	14-16	3.6	1.5	1.5	1.2	0.0	0.0	0.0
Representative Preferred	On	12-14	3.6	1.7	1.5	1.5	0.0	0.0	0.0
Representative Preferred	Off	12-14	3.6	1.9	1.5	1.5	0.9	0.0	0.0
Representative Preferred	On	10-12	3.6	3.2	2.2	1.5	1.5	0.0	0.0
Representative Preferred	Off	10-12	3.6	3.3	2.5	1.5	1.5	0.8	0.0

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
Representative Preferred	On	< 10	3.6	3.6	3.6	2.1	1.5	1.3	0.0
Representative Preferred	Off	< 10	3.6	3.6	3.6	2.5	1.5	1.5	0.0

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-17
Effects of Conservation Activity Modeling Assumptions on Lake Mead Dead Pool-Related Reductions (maf)

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
CCS Comparative Baseline	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	On	14-16	1.1	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	Off	14-16	1.1	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	On	12-14	2.4	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	Off	12-14	2.4	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	On	10-12	4.0	1.4	0.4	0.0	0.0	0.0	0.0
CCS Comparative Baseline	Off	10-12	4.0	1.4	0.4	0.0	0.0	0.0	0.0
CCS Comparative Baseline	On	< 10	6.2	3.0	2.0	0.2	0.0	0.0	0.0
CCS Comparative Baseline	Off	< 10	6.3	3.0	1.9	0.1	0.0	0.0	0.0
No Action	On	> 16	1.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	Off	> 16	1.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	On	14-16	1.5	0.3	0.0	0.0	0.0	0.0	0.0
No Action	Off	14-16	1.5	0.3	0.0	0.0	0.0	0.0	0.0
No Action	On	12-14	3.8	0.8	0.3	0.0	0.0	0.0	0.0
No Action	Off	12-14	3.8	0.8	0.3	0.0	0.0	0.0	0.0
No Action	On	10-12	5.5	2.5	1.5	0.4	0.0	0.0	0.0
No Action	Off	10-12	5.5	2.5	1.5	0.4	0.0	0.0	0.0
No Action	On	< 10	6.5	4.0	3.1	1.5	0.0	0.0	0.0
No Action	Off	< 10	6.6	4.0	3.2	1.5	0.0	0.0	0.0
Basic Coordination	On	> 16	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	Off	> 16	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	On	14-16	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	Off	14-16	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	On	12-14	1.9	0.1	0.0	0.0	0.0	0.0	0.0
Basic Coordination	Off	12-14	1.9	0.1	0.0	0.0	0.0	0.0	0.0
Basic Coordination	On	10-12	4.4	1.1	0.4	0.0	0.0	0.0	0.0
Basic Coordination	Off	10-12	4.4	1.1	0.4	0.0	0.0	0.0	0.0

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
Basic Coordination	On	< 10	6.1	2.9	1.6	0.0	0.0	0.0	0.0
Basic Coordination	Off	< 10	6.1	2.9	1.5	0.0	0.0	0.0	0.0
Enhanced Coordination	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	On	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	On	12-14	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	12-14	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	On	10-12	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	10-12	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	On	< 10	3.9	1.1	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	Off	< 10	3.8	1.3	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	14-16	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	12-14	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	10-12	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	10-12	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	On	< 10	3.4	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	Off	< 10	2.8	0.3	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	12-14	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	12-14	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	10-12	1.7	0.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	10-12	1.7	0.3	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	On	< 10	4.3	1.5	0.2	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	Off	< 10	4.3	1.5	0.4	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	14-16	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	12-14	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	12-14	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	On	10-12	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	10-12	1.9	0.3	0.0	0.0	0.0	0.0	0.0

Alternative	Conservation Activity	Flow Category	Max	90%	75%	50%	25%	10%	Min
Supply Driven (LB Pro Rata)	On	< 10	4.3	1.2	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	Off	< 10	4.3	1.5	0.3	0.0	0.0	0.0	0.0
Representative Preferred	On	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	Off	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	On	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	Off	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	On	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	Off	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	On	10-12	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	Off	10-12	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	On	< 10	3.8	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	Off	< 10	3.8	0.1	0.0	0.0	0.0	0.0	0.0

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-18
Effects of Conservation Activity Modeling Assumptions on Lower Basin Depletions (Percent of Apportionment)

Alternative	Conservation Activity	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	On	> 16	119.6	112.6	106.2	102.9	94.1	92.8	84.5
CCS Comparative Baseline	Off	> 16	119.3	113.1	107.9	100.0	93.2	93.2	84.7
CCS Comparative Baseline	On	14-16	118.1	104.6	100.6	94.1	90.0	87.2	72.5
CCS Comparative Baseline	Off	14-16	118.3	104.6	100.0	93.2	88.7	86.8	72.1
CCS Comparative Baseline	On	12-14	115.8	100.9	94.9	89.9	85.2	85.1	58.5
CCS Comparative Baseline	Off	12-14	117.4	100.0	95.4	88.7	84.7	84.7	57.8
CCS Comparative Baseline	On	10-12	106.8	97.1	92.3	85.2	80.5	69.2	40.3
CCS Comparative Baseline	Off	10-12	107.6	97.3	88.7	84.7	80.7	69.3	40.2
CCS Comparative Baseline	On	< 10	105.6	92.9	91.2	83.4	63.1	52.1	15.8
CCS Comparative Baseline	Off	< 10	104.9	92.0	88.1	83.9	63.5	51.5	14.9
No Action	On	> 16	118.0	116.8	107.9	100.3	93.7	93.7	81.8
No Action	Off	> 16	118.0	116.8	108.9	100.0	94.4	93.3	81.8
No Action	On	14-16	118.0	100.6	100.3	93.7	93.7	90.1	76.8
No Action	Off	14-16	118.0	100.0	100.0	93.3	93.3	90.1	76.4
No Action	On	12-14	116.2	100.3	94.8	93.7	90.4	84.3	51.6
No Action	Off	12-14	116.2	100.0	94.4	93.3	90.2	84.1	51.4
No Action	On	10-12	107.3	98.7	93.7	88.7	76.5	65.4	32.5
No Action	Off	10-12	107.3	95.6	93.3	89.4	76.4	65.1	32.1

Alternative	Conservation Activity	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
No Action	On	< 10	104.1	100.0	93.7	76.8	58.3	49.0	20.6
No Action	Off	< 10	100.0	94.4	93.3	76.9	58.2	49.1	20.2
Basic Coordination	On	> 16	118.0	117.1	115.1	100.3	87.3	83.9	80.2
Basic Coordination	Off	> 16	118.0	117.0	115.5	100.0	83.6	83.6	79.9
Basic Coordination	On	14-16	118.0	100.4	100.0	87.8	83.9	83.9	74.0
Basic Coordination	Off	14-16	118.0	100.0	100.0	85.7	83.6	83.6	73.7
Basic Coordination	On	12-14	116.5	100.3	89.9	83.9	83.9	82.0	62.3
Basic Coordination	Off	12-14	116.5	100.0	89.4	83.6	83.6	82.4	62.4
Basic Coordination	On	10-12	107.3	91.9	84.9	83.9	79.3	71.9	34.5
Basic Coordination	Off	10-12	107.3	92.3	83.6	83.6	79.6	71.6	34.2
Basic Coordination	On	< 10	104.3	89.9	86.2	83.9	66.1	51.7	15.9
Basic Coordination	Off	< 10	100.0	85.9	83.6	83.6	66.7	51.6	15.5
Enhanced Coordination	On	> 16	121.3	117.4	115.8	99.9	94.6	87.6	74.9
Enhanced Coordination	Off	> 16	119.6	117.2	115.5	100.4	100.4	100.4	72.1
Enhanced Coordination	On	14-16	119.4	103.5	98.7	94.2	82.2	78.1	65.3
Enhanced Coordination	Off	14-16	119.0	100.4	100.4	100.4	81.8	76.7	67.1
Enhanced Coordination	On	12-14	120.1	98.3	92.9	81.6	76.5	71.1	64.0
Enhanced Coordination	Off	12-14	116.4	100.4	85.4	80.4	73.6	68.9	63.7
Enhanced Coordination	On	10-12	106.1	86.0	81.3	74.3	67.6	65.7	44.0
Enhanced Coordination	Off	10-12	107.5	82.4	78.0	70.9	67.1	67.1	41.3
Enhanced Coordination	On	< 10	100.5	81.1	75.4	67.1	64.9	55.2	23.9
Enhanced Coordination	Off	< 10	100.4	75.5	68.8	67.1	67.1	52.7	25.1
Max. Operational Flexibility	On	> 16	119.6	117.5	115.6	99.5	88.4	80.3	75.3
Max. Operational Flexibility	Off	> 16	119.7	117.0	109.2	100.0	95.5	90.1	79.9
Max. Operational Flexibility	On	14-16	119.6	104.8	96.2	88.1	81.7	77.7	70.4
Max. Operational Flexibility	Off	14-16	119.3	100.0	99.0	91.4	86.0	82.4	70.1
Max. Operational Flexibility	On	12-14	118.8	93.4	87.9	82.8	77.9	75.3	63.4
Max. Operational Flexibility	Off	12-14	117.0	97.3	90.1	82.7	77.8	74.3	64.5
Max. Operational Flexibility	On	10-12	105.6	86.5	82.6	77.7	71.0	64.8	45.0
Max. Operational Flexibility	Off	10-12	106.5	88.2	78.4	73.2	69.2	65.8	38.8
Max. Operational Flexibility	On	< 10	90.6	83.0	77.9	66.5	59.6	55.2	27.5
Max. Operational Flexibility	Off	< 10	96.4	74.0	70.8	65.5	60.1	54.9	26.4
Supply Driven (LB Priority)	On	> 16	119.1	116.8	111.5	104.4	85.9	77.5	71.4
Supply Driven (LB Priority)	Off	> 16	119.4	116.5	110.3	104.8	91.2	83.7	77.1
Supply Driven (LB Priority)	On	14-16	118.7	105.8	101.2	87.3	79.8	75.7	71.4
Supply Driven (LB Priority)	Off	14-16	119.0	105.9	104.8	94.6	83.7	81.3	77.1
Supply Driven (LB Priority)	On	12-14	116.4	101.0	90.8	82.4	77.5	74.0	68.6
Supply Driven (LB Priority)	Off	12-14	111.6	105.9	100.4	83.7	81.7	77.1	68.3
Supply Driven (LB Priority)	On	10-12	109.2	91.0	84.5	79.4	75.3	71.9	58.1
Supply Driven (LB Priority)	Off	10-12	106.9	100.4	83.7	82.5	77.1	73.7	57.9

Alternative	Conservation Activity	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Supply Driven (LB Priority)	On	< 10	107.4	86.0	82.2	77.2	72.1	60.7	29.2
Supply Driven (LB Priority)	Off	< 10	105.9	83.7	83.7	79.5	72.5	59.9	29.1
Supply Driven (LB Pro Rata)	On	> 16	119.1	116.8	111.8	105.0	84.4	77.2	70.6
Supply Driven (LB Pro Rata)	Off	> 16	119.4	116.5	110.3	104.8	91.2	83.7	77.1
Supply Driven (LB Pro Rata)	On	14-16	118.7	105.9	101.1	85.7	78.7	74.8	68.5
Supply Driven (LB Pro Rata)	Off	14-16	119.0	105.9	104.8	94.5	83.7	81.4	76.3
Supply Driven (LB Pro Rata)	On	12-14	116.5	100.8	91.4	81.6	76.7	72.5	68.5
Supply Driven (LB Pro Rata)	Off	12-14	111.6	105.9	100.4	83.7	81.7	77.1	69.1
Supply Driven (LB Pro Rata)	On	10-12	109.2	91.2	82.9	77.7	73.8	71.2	56.5
Supply Driven (LB Pro Rata)	Off	10-12	106.9	100.4	83.7	82.4	77.1	74.2	56.5
Supply Driven (LB Pro Rata)	On	< 10	107.4	83.4	79.9	75.2	71.7	63.8	28.7
Supply Driven (LB Pro Rata)	Off	< 10	105.9	83.7	83.7	79.6	73.2	60.2	29.0
Representative Preferred	On	> 16	119.4	116.8	111.9	104.8	88.5	83.5	68.9
Representative Preferred	Off	> 16	119.3	116.9	110.4	105.9	84.6	83.7	63.4
Representative Preferred	On	14-16	118.8	106.8	103.0	89.0	83.5	82.0	60.0
Representative Preferred	Off	14-16	118.5	105.9	102.6	86.6	83.7	83.7	60.4
Representative Preferred	On	12-14	116.0	102.9	93.1	84.0	82.5	78.3	57.5
Representative Preferred	Off	12-14	111.6	102.6	90.9	83.7	83.7	78.9	60.4
Representative Preferred	On	10-12	111.0	93.7	85.0	82.6	74.4	63.8	45.2
Representative Preferred	Off	10-12	105.9	91.9	83.7	83.7	72.2	63.5	46.1
Representative Preferred	On	< 10	108.6	87.7	83.3	73.1	60.4	57.9	18.7
Representative Preferred	Off	< 10	105.9	83.7	83.7	72.5	60.4	59.1	18.1

Note: Lower Basin conservation activity includes assumptions related to the storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-19
Total State Shortage for Arizona (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	25.7	21.1	18.3	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	25.7	25.7	22.9	18.3	0.0	0.0	0.0
CCS Comparative Baseline	12-14	25.7	25.7	25.7	22.9	18.3	0.0	0.0
CCS Comparative Baseline	10-12	25.7	25.7	25.7	25.7	22.9	6.9	0.0
CCS Comparative Baseline	< 10	25.7	25.7	25.7	25.7	22.9	22.9	0.0
No Action	> 16	16.7	16.7	16.7	0.0	0.0	0.0	0.0
No Action	14-16	16.7	16.7	16.7	16.7	0.0	0.0	0.0
No Action	12-14	16.7	16.7	16.7	16.7	13.9	0.0	0.0
No Action	10-12	16.7	16.7	16.7	16.7	16.7	11.1	0.0
No Action	< 10	16.7	16.7	16.7	16.7	16.7	13.9	0.0
Basic Coordination	> 16	41.1	41.1	41.1	0.0	0.0	0.0	0.0
Basic Coordination	14-16	41.1	41.1	41.1	41.1	0.0	0.0	0.0
Basic Coordination	12-14	41.1	41.1	41.1	41.1	29.2	0.0	0.0
Basic Coordination	10-12	41.1	41.1	41.1	41.1	41.1	21.9	0.0
Basic Coordination	< 10	41.1	41.1	41.1	41.1	41.1	38.8	0.0
Enhanced Coordination	> 16	24.4	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	33.3	19.9	17.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	33.3	28.7	23.3	17.9	0.0	0.0	0.0
Enhanced Coordination	10-12	33.3	33.3	32.0	26.8	18.9	15.6	0.0
Enhanced Coordination	< 10	33.3	33.3	33.3	33.3	28.1	20.7	0.0
Max. Operational Flexibility	> 16	38.8	19.8	11.9	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	53.8	33.9	25.0	17.5	7.3	0.0	0.0
Max. Operational Flexibility	12-14	60.3	41.9	41.0	31.3	19.0	10.6	0.0
Max. Operational Flexibility	10-12	66.3	59.6	56.0	41.9	41.0	23.1	0.0
Max. Operational Flexibility	< 10	69.0	66.4	63.6	58.7	52.2	41.0	9.7
Supply Driven (LB Priority)	> 16	43.7	27.1	25.7	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	43.7	39.5	27.1	17.2	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	43.7	43.7	36.4	27.1	5.5	0.0	0.0
Supply Driven (LB Priority)	10-12	43.7	43.7	43.7	34.1	27.1	4.3	0.0
Supply Driven (LB Priority)	< 10	43.7	43.7	43.7	41.2	28.0	27.1	0.0
Supply Driven (LB Pro Rata)	> 16	33.0	27.1	25.1	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	33.0	31.4	27.1	17.8	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	33.0	33.0	30.4	27.1	7.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	33.0	33.0	33.0	29.8	27.1	5.7	0.0
Supply Driven (LB Pro Rata)	< 10	33.0	33.0	33.0	31.8	27.7	27.1	0.0

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Representative Preferred	> 16	60.9	41.7	8.2	0.0	0.0	0.0	0.0
Representative Preferred	14-16	67.6	41.7	41.7	6.7	0.0	0.0	0.0
Representative Preferred	12-14	68.3	47.3	41.7	41.7	0.0	0.0	0.0
Representative Preferred	10-12	70.2	64.5	55.6	41.7	38.0	0.0	0.0
Representative Preferred	< 10	70.2	67.6	67.6	53.1	33.1	27.1	0.0

Table TA 4-20
State Shortage for Arizona Priority 4 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	720.0	592.0	512.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	720.0	720.0	640.0	512.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	720.0	720.0	720.0	640.0	512.0	0.0	0.0
CCS Comparative Baseline	10-12	720.0	720.0	720.0	720.0	640.0	192.0	0.0
CCS Comparative Baseline	< 10	720.0	720.0	720.0	720.0	640.0	640.0	0.0
No Action	> 16	466.9	466.9	466.8	0.0	0.0	0.0	0.0
No Action	14-16	466.9	466.9	466.9	466.8	0.0	0.0	0.0
No Action	12-14	466.9	466.9	466.9	466.8	389.0	0.0	0.0
No Action	10-12	466.9	466.9	466.9	466.9	466.8	311.2	0.0
No Action	< 10	466.9	466.9	466.9	466.9	466.8	389.0	0.0
Basic Coordination	> 16	1,151.6	1,151.6	1,151.5	0.0	0.0	0.0	0.0
Basic Coordination	14-16	1,151.6	1,151.6	1,151.6	1,151.5	0.0	0.0	0.0
Basic Coordination	12-14	1,151.6	1,151.6	1,151.6	1,151.6	818.3	0.0	0.0
Basic Coordination	10-12	1,151.6	1,151.6	1,151.6	1,151.6	1,151.5	612.4	0.0
Basic Coordination	< 10	1,151.6	1,151.6	1,151.6	1,151.6	1,151.6	1,085.0	0.0
Enhanced Coordination	> 16	351.5	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	486.4	297.8	249.7	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	509.0	428.2	346.0	259.5	0.0	0.0	0.0
Enhanced Coordination	10-12	516.8	495.9	478.6	391.6	273.9	227.0	0.0
Enhanced Coordination	< 10	523.8	523.8	512.9	480.9	407.7	299.1	0.0
Max. Operational Flexibility	> 16	1,087.7	554.5	334.1	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	1,456.7	948.1	700.3	489.7	204.4	0.0	0.0
Max. Operational Flexibility	12-14	1,539.7	1,174.1	1,147.0	876.5	533.3	295.9	0.0
Max. Operational Flexibility	10-12	1,560.8	1,520.3	1,442.6	1,174.3	1,147.0	647.8	0.0
Max. Operational Flexibility	< 10	1,571.4	1,571.4	1,539.7	1,442.6	1,442.6	1,147.0	271.6
Supply Driven (LB Priority)	> 16	1,224.6	760.0	719.3	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	1,224.7	1,107.0	760.0	481.5	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	1,224.7	1,224.4	1,019.9	760.0	154.6	0.0	0.0
Supply Driven (LB Priority)	10-12	1,224.7	1,224.6	1,224.4	955.3	760.0	120.1	0.0
Supply Driven (LB Priority)	< 10	1,224.7	1,224.6	1,224.4	1,153.0	784.8	760.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Supply Driven (LB Pro Rata)	> 16	504.5	415.3	370.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	514.6	473.7	407.4	259.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	511.2	485.3	459.1	391.6	101.5	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	514.6	499.7	475.6	440.8	391.6	81.5	0.0
Supply Driven (LB Pro Rata)	< 10	514.6	501.3	478.8	475.6	407.4	391.6	0.0
Representative Preferred	> 16	1510.6	1167.1	229.9	0.0	0.0	0.0	0.0
Representative Preferred	14-16	1539.7	1167.1	1167.1	186.4	0.0	0.0	0.0
Representative Preferred	12-14	1550.3	1325.2	1167.1	1167.1	0.0	0.0	0.0
Representative Preferred	10-12	1560.8	1471.7	1442.6	1167.1	1063.6	0.0	0.0
Representative Preferred	< 10	1560.8	1520.3	1442.6	1442.6	926.3	760.0	0.0

Table TA 4-21
State Shortage for Arizona Priorities 2 & 3 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	185.1	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	253.2	143.6	126.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	253.2	207.4	168.3	134.8	0.0	0.0	0.0
Enhanced Coordination	10-12	253.2	247.5	227.2	196.1	143.1	116.9	0.0
Enhanced Coordination	< 10	253.2	253.2	250.2	224.6	210.1	156.5	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	62.6	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	244.7	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	414.7	187.5	80.3	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	417.0	394.5	305.2	161.3	11.9	0.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	250.5	206.2	182.9	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	250.5	223.1	206.2	133.6	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	250.5	245.3	216.7	206.2	53.5	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	250.5	250.5	240.2	208.4	204.1	41.8	0.0
Supply Driven (LB Pro Rata)	< 10	250.5	250.5	250.5	222.2	204.1	185.6	0.0
Representative Preferred	> 16	261.3	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	450.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	450.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	450.0	336.8	82.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	450.0	450.0	427.5	12.0	0.0	0.0	0.0

Table TA 4-22
State Shortage for Arizona Priority 1 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	145.6	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	199.2	117.2	101.2	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	199.2	169.2	137.1	106.7	0.0	0.0	0.0
Enhanced Coordination	10-12	199.2	196.7	187.3	158.8	112.8	92.7	0.0
Enhanced Coordination	< 10	199.2	199.2	198.0	191.0	166.8	123.7	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	197.1	162.2	147.9	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	197.1	183.8	162.2	105.6	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	197.1	195.8	177.7	162.2	42.1	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	197.1	197.1	193.9	174.3	162.2	33.8	0.0
Supply Driven (LB Pro Rata)	< 10	197.1	197.1	197.1	185.5	162.0	160.9	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-23
Total State Shortage for California (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	8.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	8.0	8.0	4.5	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	8.0	8.0	8.0	5.7	0.0	0.0	0.0
CCS Comparative Baseline	10-12	8.0	8.0	8.0	8.0	5.7	0.0	0.0
CCS Comparative Baseline	< 10	8.0	8.0	8.0	8.0	5.7	4.5	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Enhanced Coordination	> 16	24.4	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	33.3	19.9	17.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	33.3	28.7	23.3	17.9	0.0	0.0	0.0
Enhanced Coordination	10-12	33.3	33.3	32.0	26.8	18.9	15.6	0.0
Enhanced Coordination	< 10	33.3	33.3	33.3	33.3	28.1	20.7	0.0
Max. Operational Flexibility	> 16	10.0	6.0	1.8	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	12.9	10.0	8.9	4.8	0.0	0.0	0.0
Max. Operational Flexibility	12-14	21.1	10.0	10.0	10.0	5.6	1.1	0.0
Max. Operational Flexibility	10-12	28.9	18.5	13.7	10.0	10.0	7.8	0.0
Max. Operational Flexibility	< 10	29.0	28.0	23.9	17.3	10.5	10.0	0.6
Supply Driven (LB Priority)	> 16	10.0	10.0	9.2	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	10.0	10.0	10.0	4.6	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	10.0	10.0	10.0	10.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	10.0	10.0	10.0	10.0	10.0	0.0	0.0
Supply Driven (LB Priority)	< 10	10.0	10.0	10.0	10.0	10.0	10.0	0.0
Supply Driven (LB Pro Rata)	> 16	17.2	10.0	8.9	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	17.2	15.2	10.0	5.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	17.2	17.2	14.0	10.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	17.2	17.2	17.2	13.2	10.0	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	17.2	17.2	17.2	15.8	10.7	10.0	0.0
Representative Preferred	> 16	11.9	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	20.5	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	20.5	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	20.5	15.3	8.9	0.0	0.0	0.0	0.0
Representative Preferred	< 10	20.5	20.5	19.5	10.0	0.0	0.0	0.0

Table TA 4-24
State Shortage for California Priority 4 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	325.5	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	325.5	325.5	186.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	325.5	325.5	325.5	232.5	0.0	0.0	0.0
CCS Comparative Baseline	10-12	325.5	325.5	325.5	325.5	232.5	0.0	0.0
CCS Comparative Baseline	< 10	325.5	325.5	325.5	325.5	232.5	186.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	73.8	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	103.9	62.7	50.4	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	109.2	88.8	70.6	50.8	0.0	0.0	0.0
Enhanced Coordination	10-12	111.3	106.5	98.3	76.5	52.4	41.7	0.0
Enhanced Coordination	< 10	113.2	113.2	110.3	100.0	77.7	55.6	0.0
Max. Operational Flexibility	> 16	333.9	255.7	79.6	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	336.8	325.4	302.7	211.3	0.0	0.0	0.0
Max. Operational Flexibility	12-14	336.8	328.2	311.2	255.7	248.1	47.3	0.0
Max. Operational Flexibility	10-12	336.8	333.9	316.9	302.7	255.7	255.7	0.0
Max. Operational Flexibility	< 10	339.6	339.6	331.1	302.7	255.7	255.7	26.7
Supply Driven (LB Priority)	> 16	336.8	322.6	255.7	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	336.8	325.4	302.7	204.4	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	336.8	328.2	311.2	255.7	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	336.8	333.9	316.9	302.7	255.7	0.0	0.0
Supply Driven (LB Priority)	< 10	339.6	339.6	331.1	302.7	255.7	255.7	0.0
Supply Driven (LB Pro Rata)	> 16	56.5	32.8	25.6	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	57.9	44.6	32.0	13.9	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	57.4	53.0	44.0	30.3	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	57.9	55.5	52.1	40.1	25.6	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	57.9	56.0	52.1	44.0	31.7	25.6	0.0
Representative Preferred	> 16	336.8	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	336.8	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	336.8	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	336.8	319.7	255.7	0.0	0.0	0.0	0.0
Representative Preferred	< 10	339.6	339.6	328.2	255.7	0.0	0.0	0.0

Table TA 4-25
State Shortage for California Priorities 3a & 3b (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	24.5	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	24.5	24.5	14.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	24.5	24.5	24.5	17.5	0.0	0.0	0.0
CCS Comparative Baseline	10-12	24.5	24.5	24.5	24.5	17.5	0.0	0.0
CCS Comparative Baseline	< 10	24.5	24.5	24.5	24.5	17.5	14.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	228.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	327.5	188.3	162.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	327.5	271.3	221.3	172.3	0.0	0.0	0.0
Enhanced Coordination	10-12	327.5	311.8	301.7	254.1	182.2	148.9	0.0
Enhanced Coordination	< 10	327.5	327.5	311.8	311.8	269.1	199.2	0.0
Max. Operational Flexibility	> 16	184.3	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	309.7	125.9	96.1	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	674.4	184.3	137.3	114.6	0.0	0.0	0.0
Max. Operational Flexibility	10-12	982.5	517.8	300.3	184.3	125.9	62.5	0.0
Max. Operational Flexibility	< 10	982.5	931.0	749.7	448.7	168.7	137.3	0.0
Supply Driven (LB Priority)	> 16	184.3	131.6	103.9	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	184.3	184.3	128.8	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	184.3	184.3	137.3	117.4	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	184.3	184.3	184.3	131.6	106.1	0.0	0.0
Supply Driven (LB Priority)	< 10	184.3	184.3	184.3	131.6	103.2	100.4	0.0
Supply Driven (LB Pro Rata)	> 16	169.0	98.3	85.6	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	169.0	143.1	98.3	48.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	169.0	160.9	132.5	93.6	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	169.0	169.0	160.9	125.9	93.6	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	169.0	169.0	160.9	149.3	101.8	93.6	0.0
Representative Preferred	> 16	267.7	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	645.6	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	645.6	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	645.6	377.7	89.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	645.6	645.6	542.9	100.4	0.0	0.0	0.0

Table TA 4-26
State Shortage for California Priority 2 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.8	0.5	0.4	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	0.8	0.7	0.5	0.4	0.0	0.0	0.0
Enhanced Coordination	10-12	0.8	0.8	0.7	0.6	0.4	0.4	0.0
Enhanced Coordination	< 10	0.8	0.8	0.8	0.8	0.6	0.5	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	0.4	0.2	0.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.4	0.3	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.4	0.4	0.3	0.2	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	0.4	0.4	0.4	0.3	0.2	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	0.4	0.4	0.4	0.4	0.2	0.2	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-27
State Shortage for California Priority 1 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	89.8	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	122.8	73.4	62.7	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	122.8	105.8	85.9	66.0	0.0	0.0	0.0
Enhanced Coordination	10-12	122.8	122.8	118.1	98.6	69.7	57.4	0.0
Enhanced Coordination	< 10	122.8	122.8	122.8	122.8	103.4	76.3	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	30.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	34.8	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Supply Driven (LB Pro Rata)	> 16	63.4	36.8	32.8	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	63.4	56.1	36.8	18.3	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	63.4	63.4	51.6	36.8	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	63.4	63.4	63.4	48.8	36.8	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	63.4	63.4	63.4	58.2	39.5	36.8	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-28
State Shortage for California Present Perfected Rights (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	680.1	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	930.4	554.8	473.7	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	930.4	798.9	647.6	499.2	0.0	0.0	0.0
Enhanced Coordination	10-12	930.4	924.7	888.4	746.4	527.4	434.4	0.0
Enhanced Coordination	< 10	930.4	930.4	927.5	918.1	782.4	578.1	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	480.1	279.1	247.5	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	480.1	422.6	279.1	137.9	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	480.1	479.1	388.6	279.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	480.1	480.1	477.6	367.2	279.1	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	480.1	480.1	480.1	439.1	299.0	278.8	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-29
Total State Shortage for Nevada (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	10.0	8.3	7.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	10.0	10.0	9.0	7.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	10.0	10.0	10.0	9.0	7.0	0.0	0.0
CCS Comparative Baseline	10-12	10.0	10.0	10.0	10.0	9.0	2.7	0.0
CCS Comparative Baseline	< 10	10.0	10.0	10.0	10.0	9.0	9.0	0.0
No Action	> 16	11.0	11.0	11.0	0.0	0.0	0.0	0.0
No Action	14-16	11.0	11.0	11.0	11.0	0.0	0.0	0.0
No Action	12-14	11.0	11.0	11.0	11.0	9.2	0.0	0.0
No Action	10-12	11.0	11.0	11.0	11.0	11.0	7.4	0.0
No Action	< 10	11.0	11.0	11.0	11.0	11.0	9.2	0.0
Basic Coordination	> 16	27.2	27.2	27.2	0.0	0.0	0.0	0.0
Basic Coordination	14-16	27.2	27.2	27.2	27.2	0.0	0.0	0.0
Basic Coordination	12-14	27.2	27.2	27.2	27.2	19.4	0.0	0.0
Basic Coordination	10-12	27.2	27.2	27.2	27.2	27.2	14.5	0.0
Basic Coordination	< 10	27.2	27.2	27.2	27.2	27.2	25.7	0.0
Enhanced Coordination	> 16	24.4	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	33.3	19.9	17.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	33.3	28.7	23.3	17.9	0.0	0.0	0.0
Enhanced Coordination	10-12	33.3	33.3	32.0	26.8	18.9	15.6	0.0
Enhanced Coordination	< 10	33.3	33.3	33.3	33.3	28.1	20.7	0.0

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Max. Operational Flexibility	> 16	25.0	11.4	5.7	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	38.9	21.4	15.1	9.7	2.8	0.0	0.0
Max. Operational Flexibility	12-14	52.9	27.2	26.5	19.6	10.9	4.8	0.0
Max. Operational Flexibility	10-12	65.9	49.2	41.3	27.2	26.5	13.8	0.0
Max. Operational Flexibility	< 10	66.1	65.9	58.4	48.0	35.5	26.6	4.1
Supply Driven (LB Priority)	> 16	28.5	16.7	15.6	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	28.5	25.5	16.7	9.5	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	28.5	28.5	23.3	16.7	2.1	0.0	0.0
Supply Driven (LB Priority)	10-12	28.5	28.5	28.5	21.7	16.7	1.7	0.0
Supply Driven (LB Priority)	< 10	28.5	28.5	28.5	26.6	17.3	16.7	0.0
Supply Driven (LB Pro Rata)	> 16	23.3	16.7	15.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	23.3	21.5	16.7	10.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	23.3	23.3	20.4	16.7	2.7	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	23.3	23.3	23.3	19.7	16.7	2.2	0.0
Supply Driven (LB Pro Rata)	< 10	23.3	23.3	23.3	22.0	17.3	16.7	0.0
Representative Preferred	> 16	54.2	27.6	5.4	0.0	0.0	0.0	0.0
Representative Preferred	14-16	68.7	27.6	27.6	4.4	0.0	0.0	0.0
Representative Preferred	12-14	68.7	31.3	27.6	27.6	0.0	0.0	0.0
Representative Preferred	10-12	68.7	60.6	41.0	27.6	24.9	0.0	0.0
Representative Preferred	< 10	68.7	68.7	68.5	36.3	21.4	16.7	0.0

Table TA 4-30
State Shortage for Nevada Priority 8 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	30.0	25.0	21.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	30.0	30.0	27.0	21.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	30.0	30.0	30.0	27.0	21.0	0.0	0.0
CCS Comparative Baseline	10-12	30.0	30.0	30.0	30.0	27.0	8.0	0.0
CCS Comparative Baseline	< 10	30.0	30.0	30.0	30.0	27.0	27.0	0.0
No Action	> 16	33.1	33.1	33.1	0.0	0.0	0.0	0.0
No Action	14-16	33.1	33.1	33.1	33.1	0.0	0.0	0.0
No Action	12-14	33.1	33.1	33.1	33.1	27.6	0.0	0.0
No Action	10-12	33.1	33.1	33.1	33.1	33.1	22.1	0.0
No Action	< 10	33.1	33.1	33.1	33.1	33.1	27.6	0.0
Basic Coordination	> 16	81.7	81.7	81.7	0.0	0.0	0.0	0.0
Basic Coordination	14-16	81.7	81.7	81.7	81.7	0.0	0.0	0.0
Basic Coordination	12-14	81.7	81.7	81.7	81.7	58.1	0.0	0.0
Basic Coordination	10-12	81.7	81.7	81.7	81.7	81.7	43.5	0.0
Basic Coordination	< 10	81.7	81.7	81.7	81.7	81.7	77.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Enhanced Coordination	> 16	70.6	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	96.5	58.4	49.5	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	97.8	83.9	68.1	51.9	0.0	0.0	0.0
Enhanced Coordination	10-12	98.3	96.5	93.8	77.9	54.8	45.3	0.0
Enhanced Coordination	< 10	98.6	98.6	97.9	96.5	81.6	60.0	0.0
Max. Operational Flexibility	> 16	75.1	34.2	17.2	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	116.8	64.3	45.4	29.2	8.5	0.0	0.0
Max. Operational Flexibility	12-14	158.7	81.7	79.5	58.9	32.6	14.3	0.0
Max. Operational Flexibility	10-12	197.8	147.5	123.9	81.7	79.5	41.4	0.0
Max. Operational Flexibility	< 10	198.4	197.7	175.2	144.1	106.6	79.7	12.4
Supply Driven (LB Priority)	> 16	85.6	50.0	46.9	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	85.6	76.5	50.0	28.6	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	85.6	85.5	69.8	50.0	6.4	0.0	0.0
Supply Driven (LB Priority)	10-12	85.6	85.6	85.4	65.0	50.0	5.0	0.0
Supply Driven (LB Priority)	< 10	85.6	85.6	85.6	79.8	51.9	50.0	0.0
Supply Driven (LB Pro Rata)	> 16	68.6	49.0	44.4	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	68.9	63.2	48.7	29.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	68.8	67.6	59.8	48.3	7.9	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	68.9	68.3	67.6	57.3	48.3	6.4	0.0
Supply Driven (LB Pro Rata)	< 10	68.9	68.5	67.6	64.6	50.2	48.3	0.0
Representative Preferred	> 16	162.5	82.8	16.3	0.0	0.0	0.0	0.0
Representative Preferred	14-16	206.0	82.8	82.8	13.2	0.0	0.0	0.0
Representative Preferred	12-14	206.0	94.0	82.8	82.8	0.0	0.0	0.0
Representative Preferred	10-12	206.0	181.8	122.9	82.8	74.7	0.0	0.0
Representative Preferred	< 10	206.0	206.0	205.6	108.9	64.2	50.0	0.0

Table TA 4-31
State Shortage for Nevada Priority 7 (Acre-Feet)

Alternative	Flow Category	Max (af)	90% (af)	75% (af)	50% (af)	25% (af)	10% (af)	Min (af)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (af)	90% (af)	75% (af)	50% (af)	25% (af)	10% (af)	Min (af)
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	6.1	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	8.3	4.3	3.6	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	8.3	6.0	4.8	4.1	0.0	0.0	0.0
Enhanced Coordination	10-12	8.3	8.1	6.9	5.0	4.3	3.6	0.0
Enhanced Coordination	< 10	8.3	8.3	8.1	5.8	4.4	4.0	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	5.8	4.2	2.5	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	5.8	4.2	4.0	2.3	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	5.8	5.6	4.2	3.7	0.7	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	5.8	5.8	5.1	4.2	3.2	0.5	0.0
Supply Driven (LB Pro Rata)	< 10	5.8	5.8	5.8	4.2	2.9	2.2	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-32
State Shortage for Nevada Priority 2 (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.5	0.3	0.2	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	0.5	0.4	0.3	0.2	0.0	0.0	0.0
Enhanced Coordination	10-12	0.5	0.5	0.4	0.3	0.2	0.1	0.0
Enhanced Coordination	< 10	0.5	0.5	0.5	0.3	0.1	0.1	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	0.4	0.2	0.1	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.4	0.3	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.4	0.3	0.3	0.2	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	0.4	0.4	0.3	0.3	0.1	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	0.4	0.4	0.4	0.3	0.1	0.0	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-33
State Shortage for Nevada Presented Perfected Rights (kaf)

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	3.0	1.5	1.3	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	3.0	2.1	1.7	1.5	0.0	0.0	0.0
Enhanced Coordination	10-12	3.0	2.9	2.4	1.8	1.5	1.2	0.0
Enhanced Coordination	< 10	3.0	3.0	2.9	2.0	1.5	1.3	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	2.1	1.5	0.9	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	2.1	1.5	1.4	0.8	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	2.1	2.0	1.5	1.3	0.2	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	2.1	2.1	1.8	1.5	1.1	0.2	0.0
Supply Driven (LB Pro Rata)	< 10	2.1	2.1	2.1	1.5	1.0	0.7	0.0

Alternative	Flow Category	Max (kaf)	90% (kaf)	75% (kaf)	50% (kaf)	25% (kaf)	10% (kaf)	Min (kaf)
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table TA 4-34
State Depletions Arizona (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	115.3	115.3	110.0	103.5	83.0	81.1	73.3
CCS Comparative Baseline	14-16	115.3	103.5	100.0	81.7	78.8	74.3	55.0
CCS Comparative Baseline	12-14	113.9	100.0	83.9	78.7	74.3	73.7	41.3
CCS Comparative Baseline	10-12	108.6	93.1	81.1	74.3	64.8	51.9	26.2
CCS Comparative Baseline	< 10	103.5	81.6	78.0	68.8	45.7	34.4	11.4
No Action	> 16	115.3	115.3	106.8	100.0	83.3	82.9	61.7
No Action	14-16	115.3	100.0	100.0	83.3	82.8	76.7	56.9
No Action	12-14	113.7	100.0	86.0	83.3	76.9	66.3	29.9
No Action	10-12	106.6	91.9	83.3	74.2	56.2	45.0	17.9
No Action	< 10	101.6	94.2	83.3	56.7	38.7	29.6	15.3
Basic Coordination	> 16	115.3	115.3	113.4	100.0	60.6	58.9	54.9
Basic Coordination	14-16	115.3	100.0	100.0	63.8	58.9	58.9	47.7
Basic Coordination	12-14	115.3	100.0	70.8	58.9	58.9	56.5	36.7
Basic Coordination	10-12	106.6	78.1	59.4	58.9	53.1	45.4	20.1
Basic Coordination	< 10	102.0	66.9	61.5	58.9	41.3	30.8	11.2
Enhanced Coordination	> 16	116.8	115.3	115.0	100.6	97.7	88.7	75.1
Enhanced Coordination	14-16	116.7	105.8	99.8	97.7	79.5	77.7	66.5
Enhanced Coordination	12-14	116.7	99.3	97.1	80.1	76.7	72.4	60.6
Enhanced Coordination	10-12	107.1	83.9	79.8	73.4	68.0	66.5	30.6
Enhanced Coordination	< 10	100.6	78.8	72.9	67.5	66.4	48.0	13.9
Max. Operational Flexibility	> 16	116.7	115.3	113.5	99.9	70.0	68.4	67.4
Max. Operational Flexibility	14-16	116.7	106.5	90.5	70.0	68.4	68.4	46.1
Max. Operational Flexibility	12-14	116.6	85.4	71.0	68.4	67.1	58.9	39.7
Max. Operational Flexibility	10-12	105.1	70.0	68.4	62.6	46.4	40.6	28.5
Max. Operational Flexibility	< 10	81.3	68.4	60.3	42.5	36.0	32.9	16.9
Supply Driven (LB Priority)	> 16	115.3	115.3	113.4	109.2	69.5	57.1	55.5
Supply Driven (LB Priority)	14-16	115.3	110.7	108.6	73.2	60.2	57.1	55.5
Supply Driven (LB Priority)	12-14	115.3	108.6	84.5	69.4	57.1	56.3	46.1
Supply Driven (LB Priority)	10-12	111.1	83.8	69.5	60.6	56.3	52.6	37.3
Supply Driven (LB Priority)	< 10	108.6	69.5	64.9	57.1	52.0	39.6	16.4

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Supply Driven (LB Pro Rata)	> 16	115.3	115.3	113.4	109.9	69.9	57.3	56.5
Supply Driven (LB Pro Rata)	14-16	115.3	110.7	108.5	76.0	63.0	57.6	56.5
Supply Driven (LB Pro Rata)	12-14	115.3	108.6	85.6	69.5	62.8	57.2	49.9
Supply Driven (LB Pro Rata)	10-12	111.1	85.2	69.5	63.3	59.3	57.1	35.1
Supply Driven (LB Pro Rata)	< 10	108.6	69.5	63.9	58.2	57.1	44.5	13.0
Representative Preferred	> 16	116.8	115.3	112.9	108.6	73.8	59.5	40.6
Representative Preferred	14-16	116.7	110.0	108.6	74.4	59.8	58.5	32.4
Representative Preferred	12-14	115.9	108.6	86.4	60.4	58.5	56.7	31.7
Representative Preferred	10-12	111.3	89.9	67.7	58.5	48.2	35.9	24.5
Representative Preferred	< 10	110.0	73.0	59.3	51.8	32.9	31.0	14.9

Table TA 4-35
State Depletions California (Percent of Apportionments)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	126.3	110.0	105.6	101.9	100.0	99.2	91.9
CCS Comparative Baseline	14-16	125.8	105.6	100.3	100.0	95.8	92.0	83.8
CCS Comparative Baseline	12-14	122.0	101.1	100.0	96.6	92.0	92.0	70.6
CCS Comparative Baseline	10-12	105.6	100.0	99.4	92.0	90.3	81.3	51.4
CCS Comparative Baseline	< 10	105.6	100.0	99.4	92.0	76.1	64.2	17.8
No Action	> 16	120.2	118.8	109.1	100.0	100.0	100.0	92.8
No Action	14-16	120.2	100.6	100.0	100.0	100.0	98.8	89.8
No Action	12-14	118.7	100.0	100.0	100.0	99.0	96.0	65.7
No Action	10-12	109.1	100.0	100.0	98.4	90.3	79.5	42.9
No Action	< 10	109.1	100.6	100.0	90.9	72.5	62.3	25.5
Basic Coordination	> 16	120.2	118.9	116.5	100.6	100.0	100.0	97.1
Basic Coordination	14-16	120.2	105.1	100.0	100.0	100.0	100.0	92.0
Basic Coordination	12-14	118.7	100.6	100.0	100.0	100.0	99.0	80.4
Basic Coordination	10-12	109.1	100.0	100.0	100.0	97.1	90.0	43.2
Basic Coordination	< 10	109.1	100.6	100.0	100.0	83.6	66.6	18.7
Enhanced Coordination	> 16	124.6	119.5	117.2	100.5	96.1	86.0	71.5
Enhanced Coordination	14-16	123.4	105.7	100.4	94.9	83.3	75.9	61.9
Enhanced Coordination	12-14	123.5	100.1	92.0	81.9	74.2	68.3	60.2
Enhanced Coordination	10-12	110.4	87.4	81.0	72.5	66.5	62.7	45.5
Enhanced Coordination	< 10	105.6	81.0	73.3	66.6	62.8	59.5	30.2
Max. Operational Flexibility	> 16	123.5	119.8	117.3	100.6	96.6	83.8	78.2
Max. Operational Flexibility	14-16	123.4	106.8	101.3	97.6	89.1	79.7	77.9
Max. Operational Flexibility	12-14	122.8	100.5	97.8	91.2	83.4	79.3	77.1
Max. Operational Flexibility	10-12	109.3	97.7	93.3	87.3	81.8	79.0	56.4
Max. Operational Flexibility	< 10	105.8	96.2	88.2	81.4	75.7	71.0	35.1

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Supply Driven (LB Priority)	> 16	123.1	118.7	111.6	102.8	95.3	82.5	78.4
Supply Driven (LB Priority)	14-16	122.3	106.8	100.6	96.3	87.0	79.7	77.8
Supply Driven (LB Priority)	12-14	117.7	104.9	98.8	90.3	83.5	79.4	78.3
Supply Driven (LB Priority)	10-12	110.5	99.4	94.6	88.5	83.3	79.3	67.5
Supply Driven (LB Priority)	< 10	107.0	99.5	93.8	86.9	79.8	74.5	37.0
Supply Driven (LB Pro Rata)	> 16	122.9	118.8	112.1	103.2	91.0	84.2	72.0
Supply Driven (LB Pro Rata)	14-16	122.3	106.0	99.2	92.5	85.3	78.7	71.4
Supply Driven (LB Pro Rata)	12-14	118.9	100.6	95.0	88.6	81.8	77.5	71.4
Supply Driven (LB Pro Rata)	10-12	110.5	95.0	90.3	84.9	79.3	74.2	64.9
Supply Driven (LB Pro Rata)	< 10	107.0	94.6	88.1	82.8	77.5	72.3	39.5
Representative Preferred	> 16	122.7	118.6	113.4	101.9	98.3	96.6	80.0
Representative Preferred	14-16	121.5	109.7	101.4	98.9	96.6	90.3	78.8
Representative Preferred	12-14	117.5	103.0	100.0	98.3	94.5	84.8	73.5
Representative Preferred	10-12	113.4	100.0	98.9	95.8	86.1	79.9	60.3
Representative Preferred	< 10	109.8	99.8	98.3	86.0	78.9	74.7	20.8

Table TA 4-36
State Depletions Nevada (Percent of Apportionment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	146.8	133.3	113.5	110.5	106.2	104.8	79.0
CCS Comparative Baseline	14-16	145.9	112.6	110.5	106.2	104.8	103.8	85.8
CCS Comparative Baseline	12-14	145.0	110.7	110.5	105.8	103.8	103.8	54.7
CCS Comparative Baseline	10-12	126.7	110.5	106.2	103.8	96.8	76.9	17.4
CCS Comparative Baseline	< 10	120.2	106.8	103.8	86.3	66.1	46.0	2.8
No Action	> 16	210.5	143.8	134.1	110.5	103.1	99.5	71.3
No Action	14-16	186.6	129.7	110.5	103.1	99.5	89.5	62.8
No Action	12-14	201.3	110.5	108.3	99.5	90.0	77.8	22.2
No Action	10-12	172.9	110.5	101.3	86.5	64.5	47.7	7.9
No Action	< 10	131.6	129.7	99.9	66.8	40.2	24.9	2.7
Basic Coordination	> 16	183.3	143.8	132.0	111.7	98.9	83.3	68.9
Basic Coordination	14-16	183.3	120.6	110.5	99.5	83.3	83.3	56.4
Basic Coordination	12-14	183.3	111.7	106.8	83.3	83.3	72.4	34.3
Basic Coordination	10-12	183.3	110.5	83.3	83.3	66.3	53.1	10.8
Basic Coordination	< 10	127.4	111.7	86.5	83.3	45.9	27.3	2.8
Enhanced Coordination	> 16	160.3	140.1	128.7	109.7	95.3	94.9	76.9
Enhanced Coordination	14-16	150.9	117.8	108.9	100.8	94.9	80.0	74.2
Enhanced Coordination	12-14	145.9	109.8	104.9	97.2	87.3	78.1	74.0
Enhanced Coordination	10-12	130.5	106.8	101.0	92.1	81.5	75.3	41.4
Enhanced Coordination	< 10	113.5	103.8	92.1	83.1	72.6	65.8	9.2

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Max. Operational Flexibility	> 16	146.8	139.2	126.4	108.6	94.4	80.6	72.3
Max. Operational Flexibility	14-16	146.8	122.0	109.7	100.9	89.0	79.8	70.5
Max. Operational Flexibility	12-14	145.9	110.0	103.6	97.2	85.4	76.4	58.8
Max. Operational Flexibility	10-12	133.9	102.1	97.2	90.2	75.0	61.5	32.5
Max. Operational Flexibility	< 10	124.1	97.2	88.9	69.8	52.0	43.5	8.4
Supply Driven (LB Priority)	> 16	146.8	134.1	124.9	111.4	96.2	80.7	74.6
Supply Driven (LB Priority)	14-16	145.9	116.2	109.6	100.4	88.7	80.5	74.6
Supply Driven (LB Priority)	12-14	134.1	111.2	105.8	98.2	87.0	78.7	74.6
Supply Driven (LB Priority)	10-12	123.6	109.4	102.6	94.2	82.5	76.0	51.4
Supply Driven (LB Priority)	< 10	118.1	107.3	98.4	83.1	73.3	61.8	4.0
Supply Driven (LB Pro Rata)	> 16	146.8	134.7	125.0	112.3	97.8	81.8	74.3
Supply Driven (LB Pro Rata)	14-16	145.9	116.2	109.7	100.6	88.7	80.1	74.3
Supply Driven (LB Pro Rata)	12-14	134.1	111.2	106.0	98.2	86.9	78.4	74.3
Supply Driven (LB Pro Rata)	10-12	123.6	108.9	104.0	95.7	84.7	75.6	56.2
Supply Driven (LB Pro Rata)	< 10	118.1	107.2	101.0	86.6	74.3	73.1	11.3
Representative Preferred	> 16	158.5	136.2	123.9	110.4	97.2	83.7	57.5
Representative Preferred	14-16	150.2	115.3	107.8	101.4	89.7	80.4	43.0
Representative Preferred	12-14	146.5	110.2	104.2	96.1	85.5	77.3	43.0
Representative Preferred	10-12	132.4	106.6	100.5	89.7	74.7	58.3	24.8
Representative Preferred	< 10	119.0	103.3	91.2	73.3	53.1	43.0	2.8

Table TA 4-37
Water Delivery Reductions to Mexico (Percent of Allotment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	18.3	6.9	5.3	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	18.3	18.3	9.7	5.3	0.0	0.0	0.0
CCS Comparative Baseline	12-14	18.3	18.3	18.3	10.3	5.3	0.0	0.0
CCS Comparative Baseline	10-12	18.3	18.3	18.3	18.3	10.3	2.7	0.0
CCS Comparative Baseline	< 10	18.3	18.3	18.3	18.3	10.3	9.7	0.0
No Action	> 16	6.7	6.7	6.7	0.0	0.0	0.0	0.0
No Action	14-16	6.7	6.7	6.7	6.7	0.0	0.0	0.0
No Action	12-14	6.7	6.7	6.7	6.7	5.6	0.0	0.0
No Action	10-12	6.7	6.7	6.7	6.7	6.7	4.4	0.0
No Action	< 10	6.7	6.7	6.7	6.7	6.7	5.6	0.0
Basic Coordination	> 16	16.4	16.4	16.4	0.0	0.0	0.0	0.0
Basic Coordination	14-16	16.4	16.4	16.4	16.4	0.0	0.0	0.0
Basic Coordination	12-14	16.4	16.4	16.4	16.4	11.7	0.0	0.0
Basic Coordination	10-12	16.4	16.4	16.4	16.4	16.4	8.7	0.0
Basic Coordination	< 10	16.4	16.4	16.4	16.4	16.4	15.5	0.0

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
Enhanced Coordination	> 16	24.4	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	33.3	19.9	17.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	33.3	28.7	23.3	17.9	0.0	0.0	0.0
Enhanced Coordination	10-12	33.3	33.3	32.0	26.8	18.9	15.6	0.0
Enhanced Coordination	< 10	33.3	33.3	33.3	33.3	28.1	20.7	0.0
Max. Operational Flexibility	> 16	21.4	11.4	5.7	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	29.2	19.4	15.1	9.7	2.8	0.0	0.0
Max. Operational Flexibility	12-14	37.0	22.6	22.2	18.3	10.9	4.8	0.0
Max. Operational Flexibility	10-12	44.3	35.0	30.5	22.6	22.2	13.8	0.0
Max. Operational Flexibility	< 10	44.5	44.3	40.2	34.3	27.3	22.2	4.1
Supply Driven (LB Priority)	> 16	23.3	16.7	15.6	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	23.3	21.6	16.7	9.5	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	23.3	23.3	20.4	16.7	2.1	0.0	0.0
Supply Driven (LB Priority)	10-12	23.3	23.3	23.3	19.5	16.7	1.7	0.0
Supply Driven (LB Priority)	< 10	23.3	23.3	23.3	22.3	17.0	16.7	0.0
Supply Driven (LB Pro Rata)	> 16	23.3	16.7	15.2	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	23.3	21.5	16.7	10.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	23.3	23.3	20.4	16.7	2.7	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	23.3	23.3	23.3	19.7	16.7	2.2	0.0
Supply Driven (LB Pro Rata)	< 10	23.3	23.3	23.3	22.0	17.3	16.7	0.0
Representative Preferred	> 16	31.9	16.7	3.3	0.0	0.0	0.0	0.0
Representative Preferred	14-16	40.0	16.7	16.7	2.7	0.0	0.0	0.0
Representative Preferred	12-14	40.0	18.9	16.7	16.7	0.0	0.0	0.0
Representative Preferred	10-12	40.0	35.6	24.6	16.7	16.7	0.0	0.0
Representative Preferred	< 10	40.0	40.0	40.0	23.6	16.7	14.3	0.0

Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-38
Annual Depletions in Mexico (Percent of Allotment)

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
CCS Comparative Baseline	> 16	111.2	111.2	107.1	101.8	96.5	91.5	77.7
CCS Comparative Baseline	14-16	111.2	106.1	101.3	96.5	91.0	81.7	68.9
CCS Comparative Baseline	12-14	111.2	101.8	96.5	91.0	81.7	80.2	55.0
CCS Comparative Baseline	10-12	108.8	96.5	91.0	81.7	76.6	65.8	38.4
CCS Comparative Baseline	< 10	107.1	91.0	85.7	77.7	59.5	48.6	12.7

Alternative	Flow Category	Max (%)	90% (%)	75% (%)	50% (%)	25% (%)	10% (%)	Min (%)
No Action	> 16	111.2	111.2	101.7	100.0	93.3	93.3	81.8
No Action	14-16	111.2	101.7	100.0	93.3	93.3	90.0	76.7
No Action	12-14	111.2	100.0	94.4	93.3	90.3	84.3	51.6
No Action	10-12	103.6	95.6	93.3	88.7	76.5	65.5	34.2
No Action	< 10	101.7	94.4	93.3	76.8	58.4	49.1	19.4
Basic Coordination	> 16	113.3	111.2	111.2	100.0	85.2	83.6	80.1
Basic Coordination	14-16	113.3	100.5	100.0	85.2	83.6	83.6	74.0
Basic Coordination	12-14	113.3	100.0	89.1	83.6	83.6	81.9	62.2
Basic Coordination	10-12	103.6	91.8	83.6	83.6	79.3	71.8	36.2
Basic Coordination	< 10	101.7	85.2	83.6	83.6	66.1	51.8	15.2
Enhanced Coordination	> 16	113.3	111.3	111.2	100.0	83.3	83.3	75.6
Enhanced Coordination	14-16	113.3	101.3	92.8	83.3	83.3	80.6	66.7
Enhanced Coordination	12-14	111.2	87.7	83.3	83.3	77.8	71.7	65.3
Enhanced Coordination	10-12	96.6	83.3	83.3	74.0	67.9	66.7	42.4
Enhanced Coordination	< 10	96.3	83.3	83.3	67.4	66.7	54.9	24.6
Max. Operational Flexibility	> 16	111.2	111.2	111.2	98.5	87.5	78.5	75.4
Max. Operational Flexibility	14-16	111.2	104.4	96.1	87.5	78.5	78.5	67.6
Max. Operational Flexibility	12-14	111.2	92.3	87.5	78.5	78.5	74.6	61.4
Max. Operational Flexibility	10-12	101.5	87.5	81.9	78.5	68.9	62.5	44.9
Max. Operational Flexibility	< 10	92.1	78.5	78.5	65.4	57.4	53.2	28.6
Supply Driven (LB Priority)	> 16	111.2	111.2	107.2	105.0	83.3	83.3	72.2
Supply Driven (LB Priority)	14-16	111.2	105.8	103.6	83.3	83.3	83.2	70.0
Supply Driven (LB Priority)	12-14	111.2	104.4	83.3	83.3	83.3	76.7	67.8
Supply Driven (LB Priority)	10-12	107.2	83.3	83.3	83.3	76.7	74.5	58.3
Supply Driven (LB Priority)	< 10	105.6	83.3	83.3	78.3	73.9	60.5	30.5
Supply Driven (LB Pro Rata)	> 16	111.2	111.2	107.2	105.6	83.3	83.3	76.2
Supply Driven (LB Pro Rata)	14-16	111.2	105.8	103.6	83.3	83.3	82.1	68.9
Supply Driven (LB Pro Rata)	12-14	111.2	103.6	83.3	83.3	83.3	76.7	67.8
Supply Driven (LB Pro Rata)	10-12	107.2	83.3	83.3	83.3	76.7	76.7	56.7
Supply Driven (LB Pro Rata)	< 10	105.6	83.3	83.3	79.2	76.7	63.9	29.7
Representative Preferred	> 16	113.3	111.2	108.3	105.6	83.3	83.3	68.1
Representative Preferred	14-16	112.3	105.6	105.6	83.3	83.3	83.3	60.0
Representative Preferred	12-14	110.6	105.6	83.3	83.3	83.3	82.7	60.0
Representative Preferred	10-12	106.5	83.3	83.3	83.3	76.9	64.4	43.5
Representative Preferred	< 10	105.6	83.3	83.3	81.5	60.0	59.5	21.3

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 4-40
Annual Upper Basin Conservation Activity: Upper Basin Total Accumulated Stored Water (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	2.0	2.0	2.0	1.9	0.9	0.5	0.0
Enhanced Coordination	14-16	2.0	2.0	2.0	1.2	0.4	0.1	0.0
Enhanced Coordination	12-14	2.0	2.0	1.7	0.5	0.1	0.0	0.0
Enhanced Coordination	10-12	2.0	1.8	0.8	0.2	0.0	0.0	0.0
Enhanced Coordination	< 10	2.0	1.1	0.3	0.0	0.0	0.0	0.0
Max. Operational Flexibility	> 16	3.0	3.0	2.2	1.4	0.4	0.2	0.0
Max. Operational Flexibility	14-16	3.0	3.0	3.0	2.0	1.1	0.7	0.1
Max. Operational Flexibility	12-14	3.0	3.0	2.9	1.7	0.7	0.4	0.0
Max. Operational Flexibility	10-12	3.0	3.0	2.2	0.8	0.4	0.2	0.0
Max. Operational Flexibility	< 10	3.0	2.2	1.1	0.5	0.3	0.2	0.0
Supply Driven (LB Priority)	> 16	3.0	2.7	2.1	1.6	1.0	0.7	0.3
Supply Driven (LB Priority)	14-16	3.0	2.3	1.8	1.3	0.8	0.5	0.2
Supply Driven (LB Priority)	12-14	3.0	2.0	1.6	1.1	0.6	0.4	0.1
Supply Driven (LB Priority)	10-12	3.0	1.7	1.3	0.7	0.3	0.2	0.0
Supply Driven (LB Priority)	< 10	3.0	1.5	1.0	0.4	0.1	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	3.0	2.7	2.1	1.6	1.0	0.7	0.3
Supply Driven (LB Pro Rata)	14-16	3.0	2.3	1.8	1.3	0.8	0.5	0.2
Supply Driven (LB Pro Rata)	12-14	3.0	2.0	1.6	1.1	0.6	0.4	0.1
Supply Driven (LB Pro Rata)	10-12	3.0	1.7	1.3	0.7	0.3	0.2	0.0
Supply Driven (LB Pro Rata)	< 10	3.0	1.5	1.0	0.4	0.1	0.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Representative Preferred	> 16	3.0	2.4	1.9	1.4	1.0	0.7	0.3
Representative Preferred	14-16	3.0	2.1	1.6	1.2	0.8	0.5	0.2
Representative Preferred	12-14	2.8	1.7	1.4	1.0	0.6	0.3	0.1
Representative Preferred	10-12	2.6	1.5	1.1	0.7	0.3	0.2	0.0
Representative Preferred	< 10	2.6	1.3	0.8	0.3	0.1	0.0	0.0

Table TA 4-41
Annual Upper Basin Conservation Activity: Upper Basin Total Annual Creation (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	0.4	0.3	0.2	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.4	0.3	0.2	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	0.4	0.4	0.2	0.1	0.0	0.0	0.0
Enhanced Coordination	10-12	0.4	0.4	0.2	0.0	0.0	0.0	0.0
Enhanced Coordination	< 10	0.4	0.3	0.2	0.0	0.0	0.0	0.0
Max. Operational Flexibility	> 16	0.5	0.5	0.5	0.3	0.2	0.0	0.0
Max. Operational Flexibility	14-16	0.5	0.5	0.3	0.2	0.0	0.0	0.0
Max. Operational Flexibility	12-14	0.5	0.5	0.3	0.2	0.0	0.0	0.0
Max. Operational Flexibility	10-12	0.5	0.5	0.3	0.2	0.0	0.0	0.0
Max. Operational Flexibility	< 10	0.5	0.5	0.3	0.2	0.0	0.0	0.0
Supply Driven (LB Priority)	> 16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.2	0.2	0.1	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Pro Rata)	> 16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Representative Preferred	> 16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Representative Preferred	14-16	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Representative Preferred	12-14	0.2	0.2	0.2	0.1	0.0	0.0	0.0
Representative Preferred	10-12	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.2	0.2	0.1	0.0	0.0	0.0	0.0

Table TA 4-42
Annual Upper Basin Conservation Activity: Upper Basin Total Annual Conversion (maf)

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
CCS Comparative Baseline	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCS Comparative Baseline	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basic Coordination	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	> 16	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	14-16	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Enhanced Coordination	12-14	0.3	0.2	0.1	0.0	0.0	0.0	0.0
Enhanced Coordination	10-12	0.5	0.2	0.1	0.0	0.0	0.0	0.0
Enhanced Coordination	< 10	0.5	0.2	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	14-16	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Max. Operational Flexibility	12-14	1.0	0.3	0.1	0.0	0.0	0.0	0.0
Max. Operational Flexibility	10-12	1.0	0.4	0.3	0.1	0.0	0.0	0.0
Max. Operational Flexibility	< 10	2.6	0.8	0.4	0.0	0.0	0.0	0.0

Alternative	Flow Category	Max (maf)	90% (maf)	75% (maf)	50% (maf)	25% (maf)	10% (maf)	Min (maf)
Supply Driven (LB Priority)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Priority)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supply Driven (LB Pro Rata)	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	> 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	14-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	12-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Representative Preferred	< 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Technical Appendix 5

Geomorphology and Sediment

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CCS	Continued Current Strategies
cfs	cubic feet per second
DMDU	Decision Making under Deep Uncertainty
HFE	high-flow experiment
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LTEMP	Long-Term Experimental Management Plan
maf	million acre-feet
RM	river mile
USGS	United States Geological Survey

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TA 5. Geomorphology and Sediment

TA 5.1 Affected Environment

This section presents an overview of sediment and geomorphic features in the Colorado River study area. The influx and efflux of sediment result in spatial and temporal variations in sandbars and channel-margin deposits throughout the Colorado River (Grams et al. 2013). Sandbar formation is a complex process that depends on:

- Flow Conditions
- Sediment Supply
- Sediment Transport
- Geomorphic Features

TA 5.1.1 Flow Conditions

Prior to the construction of the dams, the Colorado River conveyed high suspended sediment concentrations throughout most seasons during base flows and with larger flood flows (USGS 2011). The construction of Glen Canyon Dam effectively cut off approximately 95 percent of the historical sediment supply from the upper watershed (Topping et al. 2000). As a result, the Colorado River now typically transports sand downstream faster than tributaries can resupply sand on a seasonal to annual basis. This sediment deficit has resulted in progressive erosion of channel and sandbar deposits from Marble and Grand Canyons since 1963. From 1964 to 2017, net erosion occurred for approximately 69 percent of all years in Marble Canyon and for approximately 52 percent of all years in Grand Canyon (Topping et al. 2021).

Maximum releases from the dam are substantially less than historical annual peak flows, and the high-water zone has been lowered compared with the historical level. Under pre-dam conditions, sand would accumulate in Marble Canyon and upper Grand Canyon from July through March when flows were largely below 7,000 to 11,000 cubic feet per second (cfs), then erode from April to June when flows were typically higher (Topping et al. 2000). Current dam operations, under which most flows are greater than 7,000 to 11,000 cfs, do not allow for substantial sand accumulation. In conjunction with reduced sand supply, post-dam discharges have reduced the zone of annual deposition, increased the rate of sediment erosion, and contributed to the loss of beaches and sandbars (USGS 2011).

Since 1996, the Bureau of Reclamation (Reclamation) has conducted high-flow experiment (HFE) releases, managing limited sediment resources to maintain or increase sandbar size. HFE releases, which are designed to improve sediment deposition, provide the only mechanism available for sandbar building and are the most important tool for sediment resources. These water releases from Glen Canyon Dam are much larger than the base flow that is typically released. HFE releases may be

as low as 31,500 cfs, though releases of 37,000 cfs or greater are necessary for sandbar deposition (increased sandbar size) at higher elevations (Hazel et al. 2022; Salter et al. 2025). Sandbars erode between HFE releases (Hazel et al. 2022), with the highest rates immediately after a flood (when bars have the most sediment available for erosion) and decreasing with time (Grams et al. 2010). Steadier flows erode bars at a lower rate than fluctuating flows, under which high flow pulses increase velocity and shear stress (Wright et al. 2008).

Long-term rehabilitation of eddy sandbars can occur only if increases in sandbar volume caused by high flows exceed the erosion that occurs during intervening periods. HFE releases are the only existing mechanism for producing river stages high enough to contribute to significant sandbar building. More frequent HFE releases result in net increases of sandbar size given sufficiently great sand enrichment (Grams et al. 2025). Smaller amounts of deposition combined with large volumes of erosion during intervening periods result in a long-term decrease in sandbar size.

TA 5.1.2 Sediment Supply

The Paria and Little Colorado Rivers, tributaries to the Colorado River, are the major sources of sediment replenishment downstream of the dam. These tributaries affect the mechanisms that control sandbars in Marble and Grand Canyons. No major sediment source exists upstream of the Paria River, effectively making sediment a nonrenewable resource in modern-day Glen Canyon (Grams et al. 2007). Sand supplied by tributaries remains in storage for typically a few months to a year in Marble Canyon before much of it is transported downstream unless flows are below approximately 9,000 cfs (Topping et al. 2000, 2021; Rubin et al. 2002; USGS 2011).

TA 5.1.3 Sediment Transport

The Colorado River in the Grand Canyon is a sediment-supply-limited bedrock river. Releases from Glen Canyon Dam are clear, sediment-free water (Salter et al. 2025). Sediment supplied to the Colorado River comes from tributaries. Sediments are typically classified by particle size and include the following classes:

- Silt and clay (less than 0.0625 millimeters)
- Sand (0.0625 to 2.0 millimeters)
- Gravel and cobbles (2.0 to 256 millimeters)
- Boulders (greater than 256 millimeters)

In general, the term "fine sediment" refers to sediments that are sand-sized or smaller. This group makes up most of the transported sediment in the river and is carried in suspension by most dam releases. Therefore, in this analysis, unless otherwise noted as "coarse sediment," sediment and fine sediment are used interchangeably. Sand contributes the most to sediment storage, deposition rates, and downstream sand export (Topping et al. 2021). The quantity of silt and clay transported depends mainly on the tributary supply. Sandbars contain some silt and clay, but their existence primarily depends on the transport of sand. Sand sediments in the Colorado River are delivered by tributary streams, arroyos, and ephemeral[1] washes. As described above, the Paria and Little Colorado Rivers are the dominant sources. The smaller tributaries in Marble Canyon upstream from river mile (RM)

[1] A wash that flows part of the time, usually after a rainstorm, during wet weather, or for only part of the year.

30 together contribute roughly 10 percent of the sand annually supplied by the Paria River (Griffiths and Topping 2017). Downstream from RM 30, the Marble Canyon lesser tributaries supply negligible amounts of sand (Griffiths and Topping 2017, Topping et al. 2021).

The amount of sand stored within the riverbed each year depends on the highly variable tributary supply, the frequency and duration of water released from the dam, and the amount of sand already deposited on the riverbed at the beginning of the year. Sand stored on the riverbed is the principal source for building sandbars during periods of high flow releases. Sediment transport is a function of, and increases with, the volume of water flowing in the river. It also depends on changes in the sediment size and supply associated with tributary floods and dam operations, as well as the distribution of shear stress[2] across the wetted channel.

The shear stress caused by flowing water can increase the amount of sediment in suspension and the amount that is available for transport. Sediment deposition occurs wherever there is more sediment influx than efflux, but is dependent on local hydraulics, such as eddies (see **TA 5.1.4**) and the topography of the riverbed (Grams et al. 2013). The greater the river's flow, the greater its velocity, shear stress, and sediment load.

Sediment storage on the riverbed depends on the spatial variability of the riverbed (such as variations of boulders, cobbles, bedrock, and vegetation), the depth to the riverbed, and the tributary sediment supply (Rubin et al. 2020). This sediment storage, in addition to storage within sandbars and along channel margins on the Colorado River, results from coupled flow, sediment transport, and storage within fan-eddy complexes (**Figure TA 5-1**)[3] that lead to the deposition of sediments.

TA 5.1.4 Geomorphic Features

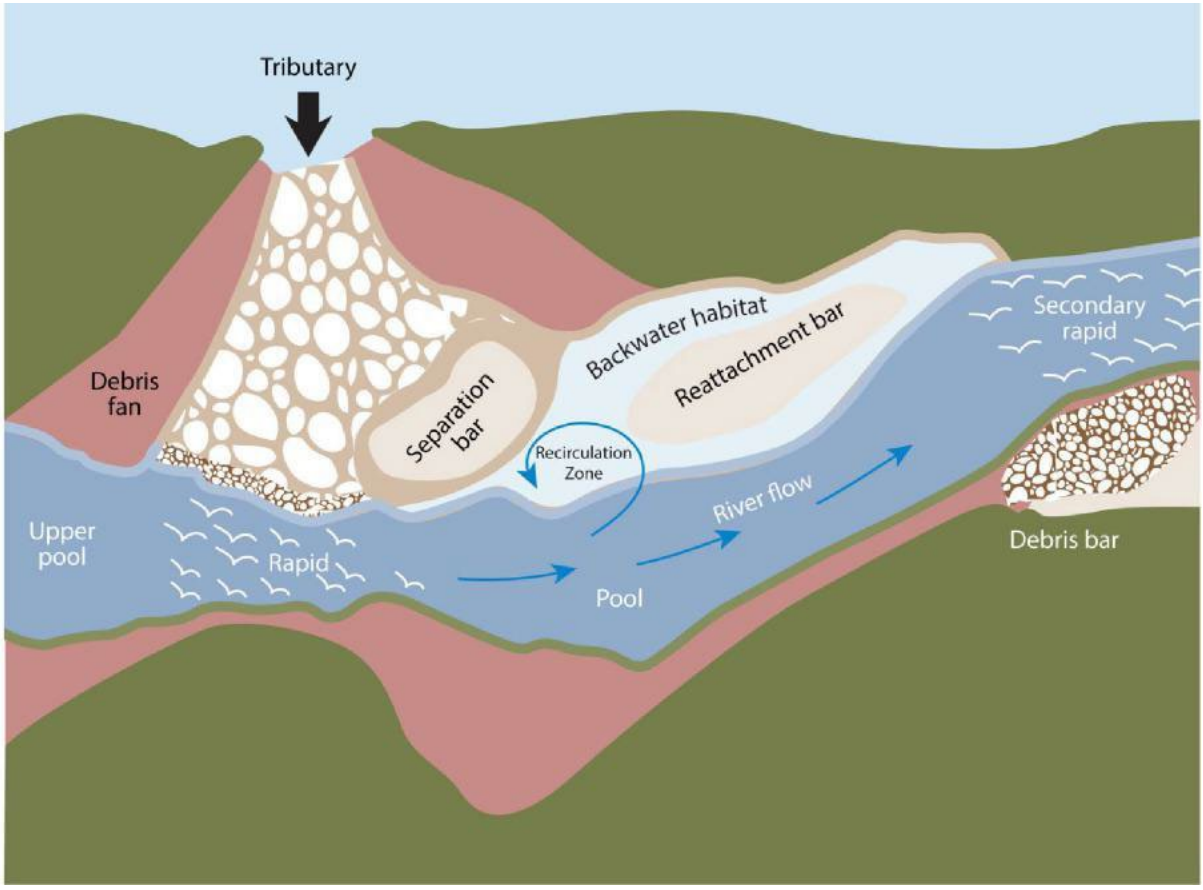
The longitudinal profile of the Colorado River consists of long, flat pool reaches with intermixed short, steep rapids. The rapids in fan-eddy complexes are typically associated with boulder rich deposits formed by tributary debris flows,[4] and flash floods. Debris fans continue to be replenished and enlarged by debris flows triggered by slope failures into tributaries. The geologic conditions favorable for debris flows from side canyons vary greatly. Debris flows tend to be high-magnitude, short-duration events. Debris flows create and maintain the rapids, control the size and location of eddies, and serve as potential sources of sand to replenish Colorado River sandbars in Marble and Grand Canyons (Schmidt and Rubin 1995; Webb and Griffiths 2001).

The coarse sediments associated with debris-fan deposits can only be mobilized during elevated flows and do not constitute a significant contribution to sediment loads transported by the river. However, their dynamics are important with respect to their retention of fine sediments and the development of fan-eddy complexes (Reclamation 2016). Debris fans extending into the Colorado River obstruct the channel, making it narrower and raising the bed elevation, which forms rapids through the point of constriction and causes the downstream-directed current to become separated

[2] The force per unit area acting parallel to a surface that causes slippage.
[3] Areas along the river where a tributary's debris fan—a sloping deposit of poorly sorted sediment ranging in size from clays and silts to larger boulders—partially blocks the river flow, causing the formation of rapids and eddies (Schmidt and Rubin 1995). Fan-eddy complexes are the controlling geomorphic feature in the Colorado River for sediment deposition.
[4] A large mass flow of sediment caused by slope failures on tributary canyons.

from the riverbank (Webb and Griffiths 2001). Downstream of the constriction, the channel is typically wider, the main current reattaches to the riverbank, and some of the water is redirected upstream. This change in flow direction forms a zone of low-velocity recirculating water (an eddy) between the points of separation and reattachment and between the main channel and riverbank (Rubin et al. 1998). These conditions allow for sediment to become entrained within the recirculation zone, where lower-velocity flows enhance the potential for sediment deposition (Schmidt and Rubin 1995).

Figure TA 5-1
Diagram of the Fan-Eddy Complex on the Colorado River



Source: Web and Griffiths 2001

Sand is deposited throughout Glen, Marble, and Grand Canyons in bars (or patches) on the riverbed, in eddies, and on terrace sandbars. Nearly all sandbars in the Grand Canyon are associated with fan-eddy complexes. In general, these complexes generate consistent sandbar features, which include separation bars and reattachment bars, based on their specific locations within the recirculation zone (USGS 2011). They continuously exchange sand with the river. Thus, the sandbars commonly found along the banks of the Colorado River are generally dynamic and unstable.

The magnitude of deposition varies by site, depending on geomorphic conditions and vegetative cover; some sandbars are stabilized by vegetation (Mueller et al. 2018; Hazel et al. 2022). Sandbars

form a fundamental element of the river landscape and are important for vegetation, riparian habitat for fish and wildlife, cultural resources, and recreation (Reclamation 1995, 2024). They form the substrate for limited riparian vegetation in this arid environment. Low-elevation sandbars create zones of low-velocity aquatic habitat (i.e., backwaters) that may be utilized by juvenile native fishes for spawning and refuge (Van Steeter and Pitlick 1998; Rubin et al. 2002). These low-elevation sandbars have been documented to be the source of sand for wind transport that helps protect archaeological resources in certain areas (East et al. 2016; Collins et al. 2016; Sankey and Draut 2014; Sankey et al. 2023a, 2023b). In addition, beaches provide some of the only camping areas for whitewater river trips, a significant driver of economic activity in the region.

TA 5.1.5 Turbidity

Turbidity is known to increase in the study area during high flows when suspended sediment concentration increases. Clear water conditions exist most of the time in the study area, interrupted by temporary periods of low visual clarity after tributary flooding (Voichick and Topping 2014). During runoff events, turbidity often exceeds the maximum recording levels of optical turbidity probes of 1,000 to 2,000 formazin nephelometric units[5]. Optical measurements of turbidity can be correlated with streamflow or with suspended sediment concentration; however, these relationships should be used with caution because, in the Colorado River, a) physical sediment characteristics are highly variable over time and b) the upper limit of measurable turbidity on optical turbidity probes is reached (Voichick and Topping 2014).

High concentrations of fine suspended sediment can increase turbidity, an optical measurement of dissolved or suspended particles in water. The relationship between turbidity and suspended sediment concentration depends on the physical properties of sediment and changes under differing conditions and sediment sources. Although higher turbidity is generally viewed as undesirable for recreational activities, it more closely reflects pre-dam conditions of the river and may therefore benefit native fish (see **TA 8**). Turbidity in the Colorado River is a natural condition and is not considered further in this section.

TA 5.1.6 Study Area

The geographic scope that would be affected by the proposed alternatives extends from Lake Powell to the Southerly International Boundary with the United Mexican States. Lake Powell has sufficient dead storage capacity to trap most incoming sediments, with only a small amount reaching areas near Glen Canyon Dam. Surveys show Lake Powell has lost approximately 13 percent of its designed dead storage capacity (Root and Jones 2022), so sedimentation is not projected to impact dam safety, power generation, or the sediment concentration at Glen Canyon Dam during the analysis timeframe of this environmental impact statement (EIS).

HFEs would have significant impacts on geomorphology and sedimentation in Marble Canyon and Grand Canyon. Since most fine sediment is transported downstream, this material will ultimately be trapped behind Hoover Dam in Lake Mead.

[5] A measure of turbidity. These formazin nephelometric unit values indicate the water has more suspended sediment and light cannot penetrate easily.

Downstream of Hoover Dam, the Colorado River functions as a sediment-starved, clearwater system. The magnitude of releases from Hoover Dam influences sediment transport capacity but does not meaningfully alter sediment supply. Consequently, this reach is defined by stable, armored bed surfaces, simplified channel morphology, and limited sandbar formation. Sediment originates primarily from reworking of fine-grained material along channel margins and bank erosion associated with sparse depositional pockets. Vegetation encroachment along banks has increased in recent decades under stabilized baseflows, further constraining areas where sediment can accumulate or be remobilized.

The only significant sediment inputs downstream of Hoover Dam are large, infrequent events on the Bill Williams River and the Gila River, affecting the reaches from Parker Dam to Imperial Dam and from Imperial Dam to the Northerly International Boundary. Ongoing Reclamation dredging operations remove this sediment at and upstream of Imperial Dam as well as upstream of Morelos Diversion Dam to improve diversion capability and to efficiently convey water to downstream users, operations which will continue under the proposed alternatives.

TA 5.2 Environmental Consequences

TA 5.2.1 Methodology

All modeling used for this resource section was based on modeling performed by the United States Geological Survey (USGS) Grand Canyon Monitoring and Research Center (Grams et al. 2025; Salter et al. 2025), using a sand routing model (Wright et al. 2010) and a sandbar response model (Mueller and Grams 2021). Input hydrologies were developed using modeling results from the Colorado River Simulation System, a long-term planning tool operated by the Bureau of Reclamation to support decision making in the Colorado River Basin and implemented in RiverWare (Zagona et al. 2001). For additional information on Colorado River Simulation System results and assumptions, please see Appendix D of Reclamation (2016).

The initial conditions (bed thicknesses and bed grain-size distribution) for the sand routing model were based on Wright et al. (2010), using a spin-up period from September 1, 2002, to October 1, 2024, and sediment inputs and gage discharges downloaded from the USGS Grand Canyon Monitoring and Research Center website (USGS 2024). Because the initial conditions for future simulations are unknown, the following idealized initial conditions were selected based on a simulation of the sand routing model and the spin-up period: a bed thickness of 0.5 meter, a lognormal bed grain size distribution with a median bed grain size of 0.3 millimeter, and a geometric standard deviation of 1. Sediment inflow projections from the Paria and Little Colorado Rivers were also generated using the Wright et al. (2010) sand routing model. This sand routing model provides sediment budget by grain size, suspended sediment concentrations, and changes in bed texture over time. Each of the 400 hydrology traces were randomly assigned a trace of Paria River sediment year inputs for sediment years 1998 to 2024. A sediment year aligns with the seasonal cycle of sediment supply and river flow, rather than the calendar year. It runs from July 1 to June 30 the following year (Topping et al. 2000).

To generate final sand routing and sandbar volume simulations, the sand routing model was rerun for each trace, with new hourly hydrographs generated by a hydropower optimization model and the same Paria River traces as in the previous round of modeling. Changes to the sediment mass balance were minimal, and HFE release durations were not modified.

HFE release magnitude and duration were selected via iteration according to the sand mass balance. USGS Grand Canyon Monitoring and Research Center modelers redistributed monthly volumes if necessary and interfaced the monthly volumes with the sand routing model by generating synthetic 15-minute hydrographs.

The output of the sand routing model provided suspended sand concentration and median grain-size inputs for the Mueller and Grams (2021) sandbar model. This model predicts long-term changes in sandbar volume in the Colorado River through the Grand Canyon based on controlled releases from Glen Canyon Dam. The sandbar model was recalibrated to the 2002–2024 period based on the long-term monitoring program. The model was initialized using the January 1, 2025, volume, and each alternative was run for all 400 traces (see **Appendix F**, Approach to Hydrologic Uncertainty, for more information on the initial conditions).

Some modifications were made to the Mueller and Grams (2021) sandbar model for this Final EIS to use additional sandbars in the calibration dataset (a total of 25 sandbars that were separated into 12 within Marble Canyon and 13 within Grand Canyon); incorporate discharge-dependence into the erosion model, rather than assuming exponential erosion with an unchanging rate constant; and assume a constant sandbar area rather than a linear relationship between sandbar area and sandbar volume (Salter et al. 2025).

Two versions of the sandbar model were used to predict sandbar deposition: one for flow rates exceeding 8,000 cfs, the average daily discharge flow; and one for flow rates exceeding 25,000 cfs, the discharge at which sandbars will not be inundated during normal dam operations and will result in usable sandbars for recreational purposes (Salter et al. 2025). Except for modeled HFEs, the sandbar model did not include any sustained releases above 25,000 cfs over the calibration period.

This technical appendix uses modeled sand transport, sandbar volumes, and reservoir operations data for the Colorado River in Grand Canyon from the USGS Grand Canyon Monitoring and Research Center (Salter and Grams 2026).

Refer to **Section 3.2**, Analysis Methods, for additional information on Decision Making Under Deep Uncertainty (DMDU) and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU conditional box plots, robustness heat maps, and vulnerability bar plots.

Impact Analysis Area

The impact analysis area used for the USGS Grand Canyon Monitoring and Research Center's sediment modeling data is the Colorado River from Glen Canyon Dam to Lake Mead, including sediment inputs from the Paria River and Little Colorado River tributaries. The analysis area for the sandbar model (quantitative model) is from Lees Ferry Gaging Station (RM 0) through Diamond Creek (RM 225). The extent of this model is limited by the availability of study sites in the

calibration dataset. However, it is expected that the finding for the reach between Lees Ferry and Diamond Creek is also representative of similar sandbars downstream to Separation Canyon (RM 240), the full-pool extent of Lake Mead.

With low Lake Mead elevations, the Colorado River will cut new paths through the mouth of the reservoir, resulting in sediment redistribution that forms new bars and alters the reservoir's delta. Finer particles may remain in suspension and travel further downstream in the reservoir before settling, increasing sediment concentration in the upper reaches of Lake Mead. Impacts on water surface elevations and consequently erosion and deposition patterns in the delta region of Lake Powell may also result. Sediment redistribution within the reservoirs is not evaluated in this EIS due to the absence of an applicable model.

The proposed alternatives may modify the magnitude, timing, or variability of releases from Hoover Dam relative to existing operations. Any such changes would affect sediment resources downstream by altering sediment transport capacity and the degree to which available fine sediment is mobilized or retained. However, because the downstream reach is sediment-starved and the alternatives would not introduce new sources of sediment, significantly modify sediment supply, or change channel morphology, any effects on geomorphology and sedimentation downstream of Hoover Dam are expected to be negligible. In all cases, sediment-related effects are expected to remain localized, reflecting the reach's supply-limited sediment regime.

Modeling Criteria and Assumptions

- For an HFE to be triggered, enough sand needs to be available in Marble Canyon (there must be a positive sand mass balance over the sediment accounting period), and enough water needs to be available in Lake Powell (as measured by the water level). Both the required amounts of sand and water depend on the selected HFE duration.
- Consistent with the 2024 Glen Canyon Dam Long-Term Experimental Management Plan (LTEMP) Supplemental EIS and Salter et al. (2025), HFE releases can only be implemented above a Lake Powell elevation of 3,500 feet, the elevation required for a release magnitude of 37,000 cfs.
- Reclamation's future operations will remain responsive to hydrology, system conditions, and applicable legal and operational requirements. Reclamation will continue to follow the 2016 Glen Canyon Dam LTEMP EIS and the 2024 LTEMP Supplemental EIS guidelines, which include the planning and implementation team process that helps assess monthly release volumes and Secretarial decision-making.
- Annual and monthly release volumes can limit the ability for an HFE release. HFE releases are offset by reducing releases from the rest of the water year, while ensuring no months go below LTEMP minimum releases in the process.
- Only sand deposited above flow rates of 25,000 cfs, which corresponds to the minimum water level that provides safety from flooding, is considered "usable" for recreational purposes.
- Sandbar deposition occurs most rapidly during the first 4 days of an HFE event, when the suspended sand concentration is largest, and the suspended sand is finest.
- Based on historical data, 60 hours is the minimum duration for an HFE to result in significant sandbar deposition.

- The transport capacity for sand during a 60-hour HFE event depends on the grain size of the accumulated sand. The average transport capacity for the 60-hour event is 294,000 metric tons, based on the analysis using the Wright et al. (2010) sand routing model.
- Sandbar erosion rates tend to be highest immediately after a flood (when bars have the most sediment available for erosion), then decrease with time (Grams et al. 2010). Steadier flows erode sandbars at a lower rate than fluctuating flows (Schmidt and Rubin 1995).
- Total discharge maximum ramp rates of 4,000 cfs per hour up and 2,500 cfs per hour down are consistent with the 2016 LTEMP EIS and 2024 LTEMP Supplemental EIS.
- Sandbar volume modeling uses the assumption that HFEs are implemented as often as possible.
- Most of the sand input from the Paria and Little Colorado Rivers occurs during the summer-fall thunderstorm season between July 1st and November 1st. A fall HFE would take full advantage of this by initiating an HFE prior to winter releases that could transport the sand downstream without the ability to aid in sandbar formation.
- During low water levels in Lake Powell, large winter releases are not a major concern. Snowpack accumulation is known prior to a possible spring HFE. This creates the option to prefer a spring HFE over a fall HFE during prolonged dry conditions, although fall HFE implementation is considered independent of a spring implementation. "Deferring," or choosing not to conduct an HFE, does not prioritize conducting an HFE during the next implementation window.
- If no HFE releases were implemented during the 1-year sediment accounting period, any positive sediment mass balance would be carried over into the next accounting period.

Impact Indicators

Issues related to geomorphology and sedimentation that are evaluated in this section are listed below.

1. Water Availability in Lake Powell
2. Sand Mass
3. HFE Frequency and Duration
4. Sandbar Volume
5. Sand Transport

TA 5.2.2 Issue 1: Water Availability

An HFE likely to enlarge sandbars requires enough water for a release rate of 37,000 cfs, generally considered the flow rate needed for significant deposition on certain sandbar types (Hazel et al. 2022). A 37,000 cfs release requires Lake Powell to be at or above 3,500 feet in April or November, when HFEs are typically scheduled. 3,500 feet also provides a 10-foot buffer above 3,490 feet – the elevation below which water can only be released through the river outlet works. As described in **Chapter 1**, **Section 1.8.4.1**, there are infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs Alternatives

that more frequently result in water levels greater than this threshold are therefore preferable. It should be noted that there are challenges to conducting HFEs at a Lake Powell elevation of 3,500 feet. Historically, the lowest elevation at which an HFE has been implemented was 3,523 feet in April 2023, when a large snowpack resulted in predictions of high rates of spring/summer runoff. Fall HFEs have not been implemented when Lake Powell water levels were below 3,590 feet.

Since the models used an elevation of 3,500 feet as the lowest possible elevation at which HFEs could occur, it is likely that the modeling overestimates the number or frequency of HFEs and underestimates the impacts on sediment related resources in the Grand Canyon for some alternatives. **Table TA 5-1** below shows the percentage of modeled HFEs by alternative that were below the historical low of 3,523 feet, including a high of 18.5 percent under the Supply Driven Alternative (both Priority and Pro Rata approaches). Notably, the two alternatives resulting in the fewest modeled HFEs below 3,523 feet –Enhanced Coordination and Maximum Operational Flexibility – result in the best overall performance with respect to geomorphology and sediment out of all the alternatives, as described in the remainder of this section.

Figure TA 5-2 below depicts the ability of each alternative to maintain a Lake Powell pool elevation greater than 3,500 feet in November or April in the specified percent of years. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative exceeds 3,500 feet in November or April in 100 percent of years. The 3,500-foot threshold was selected because it is undesirable to ever miss the opportunity to take advantage of other favorable conditions, such as large sediment loads from the Paria River.

Over the full modeling period, the Maximum Operational Flexibility Alternative is the most robust, as it met the preferred minimum performance in more than 91 percent of futures, followed by the Enhanced Coordination Alternative at 83 percent. The Representative Preferred Alternative meets the preferred minimum performance in 40 percent of futures. The Continued Current Strategies (CCS) Comparative Baseline, as well as Supply Driven (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) and Basic Coordination Alternatives, are less robust, with less than 30 percent of futures meeting the preferred minimum performance. The No Action Alternative is the least robust, with only 13 percent of futures meeting the preferred minimum performance. For all alternatives, fewer futures meet the preferred minimum performance over the full modeling period than in any subperiod. This reflects the increasing difficulty of sustaining a given level of performance over longer periods of time. Only a fraction of the futures meeting the preferred minimum performance in one subperiod also meet the preferred minimum performance in all subperiods, evidence of the interdecadal variability inherent in the ensemble of projected conditions.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Maximum Operational Flexibility (97 percent) and Enhanced Coordination (88 percent) are the most robust alternatives, followed by the Representative Preferred (60 percent). The No Action Alternative (19 percent) is the least robust, and the CCS Comparative Baseline (35 percent), Basic Coordination Alternative (36 percent), and the Supply Driven (both LB Priority and Pro Rata approaches) Alternative (46 percent) perform in the middle.

Table TA 5-1
Percentage of Modeled HFEs Above or Below the Historical Low Lake Powell Elevation (3,523 feet)

Alternative	Total number of HFEs (all years, all futures)[1]	Percent of all eligible timesteps with an HFE	Percentage of Modeled HFEs Above	Percentage of Modeled HFEs Below	Average number of HFEs/year Only Above	Average number of HFEs/year Above + Below
CCS Comparative Baseline	6,501	23.9%	85.3%	14.7%	0.41	0.48
No Action Alternative	6,478	23.9%	90.0%	12.0%	0.42	0.48
Basic Coordination Alternative	7,552	27.8%	87.2%	12.8%	0.48	0.56
Enhanced Coordination Alternative	7,897	28.9%	99.5%	0.5%	0.58	0.58
Maximum Operational Flexibility Alternative	8,846	35.5%	91.3%	8.6%	0.59	0.65
Supply Driven Alternative	7,438	27.3%	81.5%	18.5%	0.45	0.55
Representative Preferred Alternative	7,933	29.2%	86.4%	13.6%	0.50	0.58

[1] The total number of HFE eligible timesteps is 27,200 (April and November, all futures, all years)

Figure TA 5-2
Lake Powell Elevation Meeting Requirement for HFE: Robustness.
Percent of futures in which the November or April elevation exceeds 3,500 feet in the percent of years specified in each row

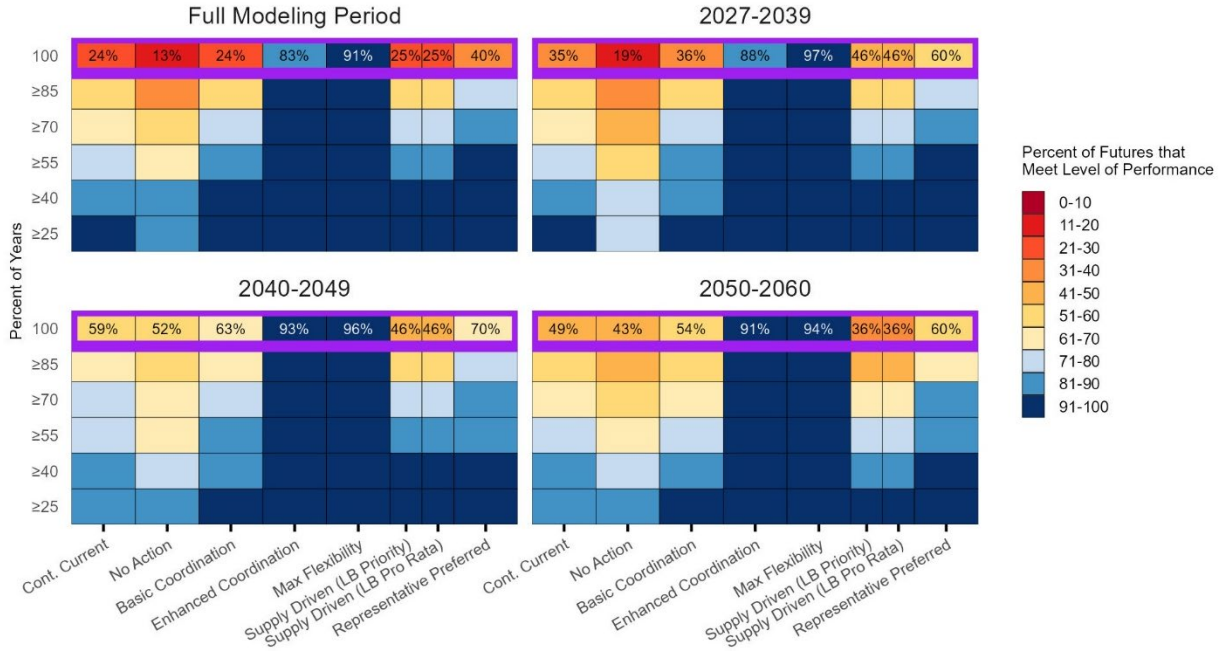


Figure TA 5-3 shows the same information as **Figure TA 5-2** but for an elevation threshold of 3,523 feet, the lowest Lake Powell elevation in the historic record. Once again, the Enhanced Coordination and Maximum Operational Flexibility Alternatives clearly outperform the other alternatives and the CCS Comparative Baseline, but the percentage of futures that meet the preferred minimum performance (26 percent and 21 percent, respectively) is substantially lower than in **Figure TA 5-2**, as an elevation of 3,500 feet is a less stringent threshold than 3,523 feet and therefore easier to achieve. In addition, whereas the Maximum Operational Flexibility Alternative is most robust for an elevation threshold of 3,500 feet (**Figure TA 5-2**), the Enhanced Coordination Alternative is most robust for an elevation threshold of 3,523 feet (**Figure TA 5-3**).

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. As in the full modeling period, Enhanced Coordination (29 percent) and Maximum Operational Flexibility (24 percent) are the most robust alternatives. The No Action Alternative is the least robust (3 percent), followed closely by the CCS Comparative Baseline (4 percent) and the Basic Coordination Alternative (6 percent). The Supply Driven (both LB Priority and Pro Rata approaches) Alternative (12 percent) and the Representative Preferred Alternative (14 percent) perform in the middle over the first modeling period.

Figure TA 5-3
Lake Powell Elevation Above Lowest Observed in HFE Implementation: Robustness. Percent of futures in which the November or April elevation exceeds 3,523 feet in the percent of years specified in each row

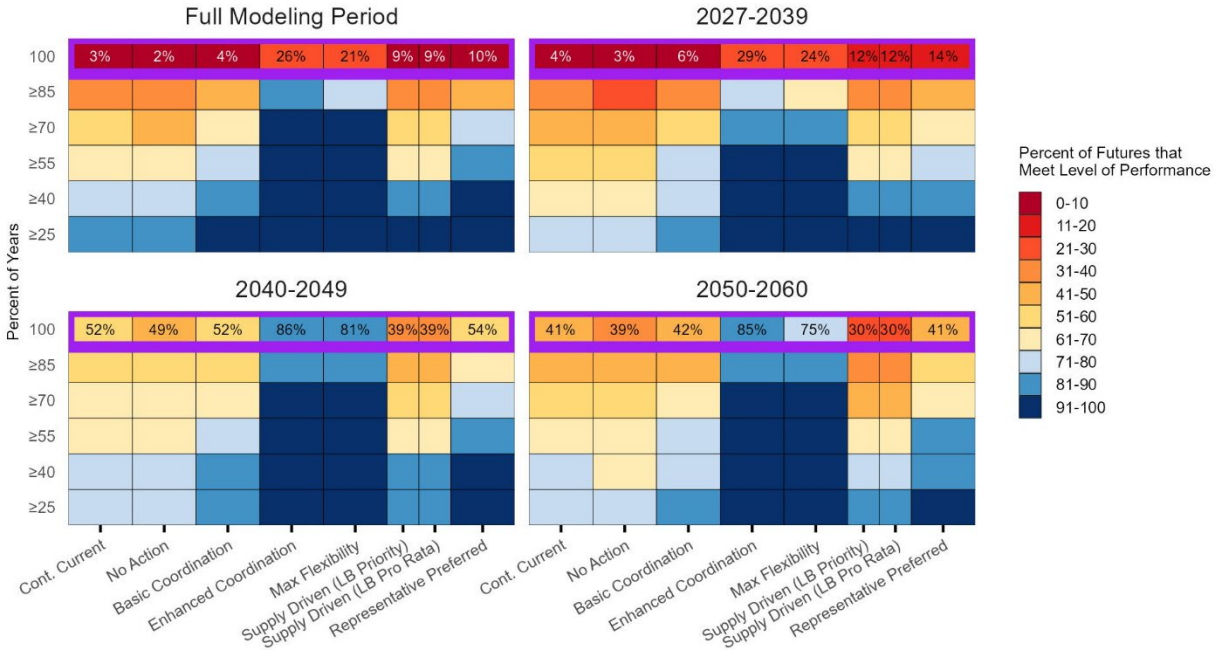


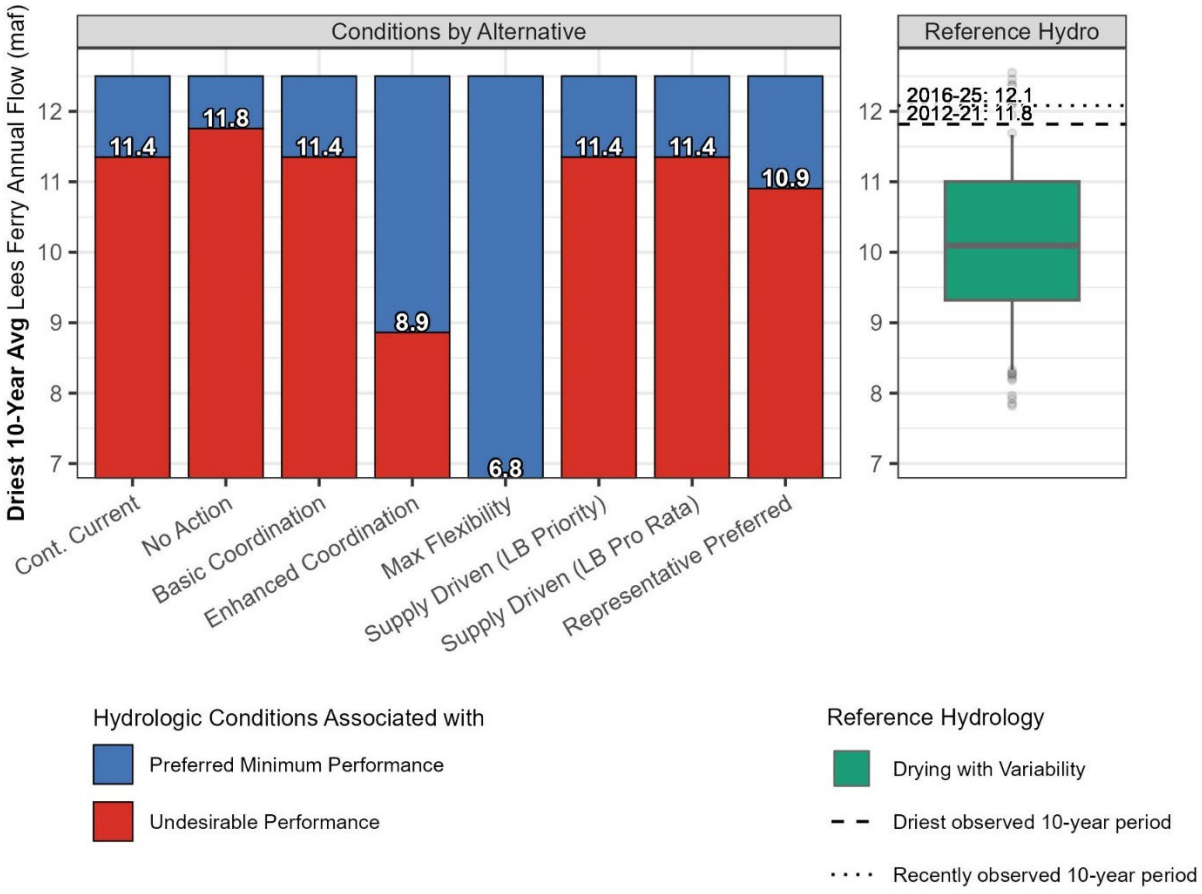
Figure TA 5-4 below shows what flow conditions are likely to cause the elevation of Lake Powell to fall below 3,500 feet in November and April in one or more sediment years. This definition of undesirable performance is based on the highlighted row in **Figure TA 5-2** above, which defined a future as successful when an alternative exceeds 3,500 feet in November or April in 100 percent of years.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be best for predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012–2021 (11.8 million acre-feet [maf]) and the average flow from 2016–2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison (see **Chapter 3, Figure 3-4**, for more information on the selected reference hydrology).

Modeling results for the CCS Comparative Baseline indicate undesirable performance under futures whose driest 10-year average flow is 11.4 maf or lower. Modeling results for the No Action (11.8 percent), Basic Coordination (11.4 percent), and Supply Driven (both LB Priority and LB Pro Rata approaches) (11.4 percent) Alternatives are comparable to the CCS Comparative Baseline, where greater than 75 percent of reference hydrology Drying with Variability traces have 10-year average annual flows drier than these alternatives (see **Appendix F**, Approach to Hydrologic Uncertainty, for more information on the Drying with Variability ensemble). Enhanced Coordination Alternative

modeling results indicate undesirable performance when the driest 10-year average flow is 8.9 maf or lower, which occurs in less than 25 percent of the Drying with Variability traces. Modeling results for the Maximum Operational Flexibility Alternative, the best performing alternative in this case, indicate undesirable performance when the driest 10-year average flow is 6.8 maf or lower, which is notably lower than the driest observed 10-year average annual flow of 11.8 maf.

Figure TA 5-4
Lake Powell Elevation Meeting Requirement for HFE: Vulnerability. Conditions that could cause Lake Powell elevation below 3,500 feet in November and April in One or More Sediment Years



Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to one or more occurrences of Lake Powell elevation falling below 3,500 feet in November and April under a 10-year average Lees Ferry annual flow of 10.9 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in about 75 percent of the traces in the Drying with Variability Ensemble, which represents a drier future.

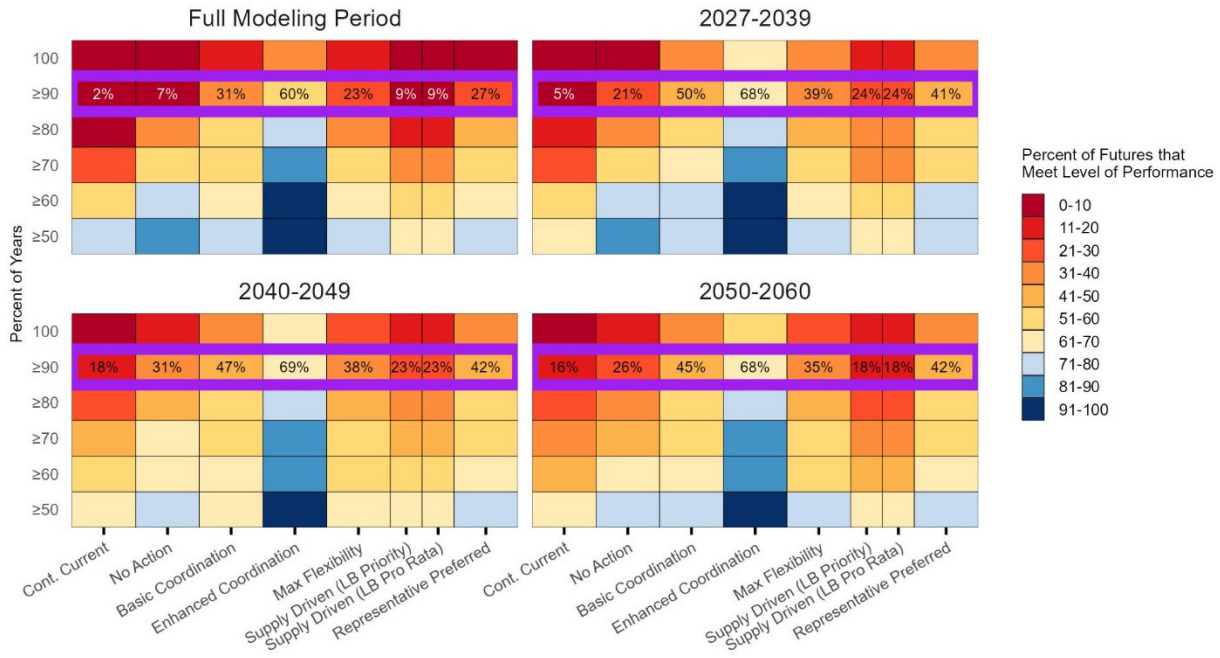
TA 5.2.3 Issue 2: Sand Mass

Sand in the Colorado River must be available to allow for downstream conveyance and sandbar deposition during an HFE release. Sand that accumulates in Marble Canyon but is transported

downstream outside HFE events does not result in sandbar formation. Sand available for sandbar building is generally supplied to the Colorado River in the late summer and early fall, the thunderstorm-induced flood season in the Paria and Little Colorado watersheds. While management under the proposed alternatives would not attempt to control the sediment generation in these tributaries, the alternatives would affect the timing and magnitude of Glen Canyon Dam releases and, therefore, the amount of sand transported outside HFE events.

Figure TA 5-5 below depicts the ability of each alternative to maintain a sediment year maximum monthly release from Glen Canyon Dam less than 900 thousand acre-feet (kaf) (approximately 15,000 cfs) in the specified percent of years. While average monthly flows must be lower than about 11,000 cfs to allow sediment accumulation under most initial conditions (bed conditions following a tributary sediment-supply event), monthly flows averaging greater than 15,000 cfs are likely to be erosive regardless of those initial conditions (Salter et al. 2025). Therefore, monthly outflows exceeding 900 kaf are considered erosive for accumulated sand. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains a sediment year maximum monthly release from Glen Canyon Dam less than 900 kaf in at least 90 percent of years.

Figure TA 5-5
Glen Canyon Dam Releases: Robustness.
Percent of futures in which the sediment year maximum monthly release is less than 900 kaf in the percent of years specified in each row



Over the full modeling period, the Enhanced Coordination Alternative is the most robust, meeting the preferred minimum performance in 60 percent of futures. The next best-performing alternatives are Basic Coordination at 31 percent, Representative Preferred Alternative at 27 percent, and Maximum Operational Flexibility at 23 percent. The No Action Alternative is the least robust, with

only 7 percent of futures meeting the preferred minimum performance. Under the CCS Comparative Baseline, as well as No Action and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, less than 10 percent of simulated futures satisfy the preferred minimum performance.

Fewer futures meet the preferred minimum performance over the full modeling period than they do in any one of the subperiods, a reflection of the increasing difficulty of sustaining this performance level over a longer period and evidence of the interdecadal variability inherent in the ensemble of projected conditions.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. Enhanced Coordination (68 percent) and Basic Coordination (50 percent) are the most robust alternatives. The CCS Comparative Baseline (5 percent) is the least robust, followed by the No Action (21 percent) and Supply Driven (both LB Priority and Pro Rata approaches) (24 percent) Alternatives. The Maximum Operational Flexibility and the Representative Preferred Alternatives perform in the middle, meeting the preferred minimum performance in 39 percent and 41 percent of futures, respectively, over the 2027-2039 modeling period.

To a certain extent, release volumes are of reduced concern due to variability throughout the sediment year and flexibility in moving water under LTEMP. If the highest releases happen before most major Paria sediment deliveries in the late summer, sediment will remain in the riverbed for a fall HFE. Under current LTEMP operations, there is flexibility to reduce releases after sediment delivery and store water that can be released during an HFE. Because of those elements, it is anticipated that in most years with reservoir elevations above 3,500 feet and average monthly releases greater than 900 kaf per month, management flexibility will be allowed for the maximum preservation of sand mass.

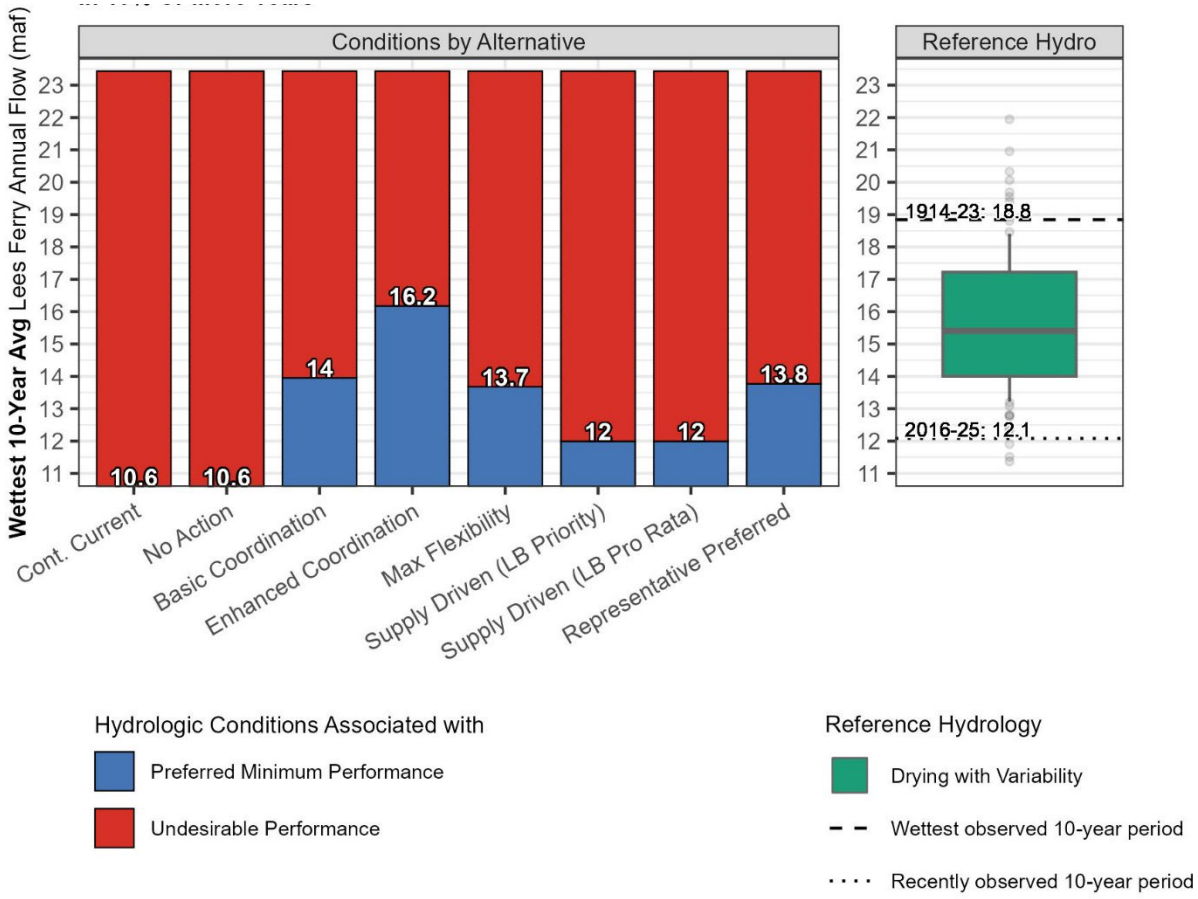
Figure TA 5-6 below shows what flow conditions are likely to cause the Glen Canyon Dam maximum monthly outflow to exceed 900 kaf in more than 10 percent of years. This definition of undesirable performance is based on the highlighted row in **Figure TA 5-5** above, which defined a future as successful when an alternative maintains a sediment year maximum monthly release from Glen Canyon Dam less than 900 kaf in at least 90 percent of years

For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914–1923 (18.8 maf) and the average flow from 2016–2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

Modeling results for the CCS Comparative Baseline and the No Action Alternative indicate undesirable performance under futures whose wettest 10-year average annual flow is 10.6 maf or higher, which is below the most recently observed 10-year average annual flow of 12.1 maf. Performance is almost as poor for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), where undesirable performance occurs under futures whose wettest 10-year average flow is 12.0 maf or higher. Under Basic Coordination and Maximum Operational Flexibility

Alternatives, undesirable performance occurs when the wettest 10-year average flow is 14.0 and 13.7 maf or higher, respectively, which occurs in about 75 percent of the projected hydrology traces. Least vulnerable to projected conditions is the Enhanced Coordination Alternative, under which undesirable performance occurs when the wettest 10-year average flow is 16.2 maf or higher, occurring in less than 50 percent of the projected hydrology traces.

Figure TA 5-6
Glen Canyon Dam Releases: Vulnerability.
Conditions that could cause the maximum monthly outflow to exceed 900 kaf in more than 10 percent of years

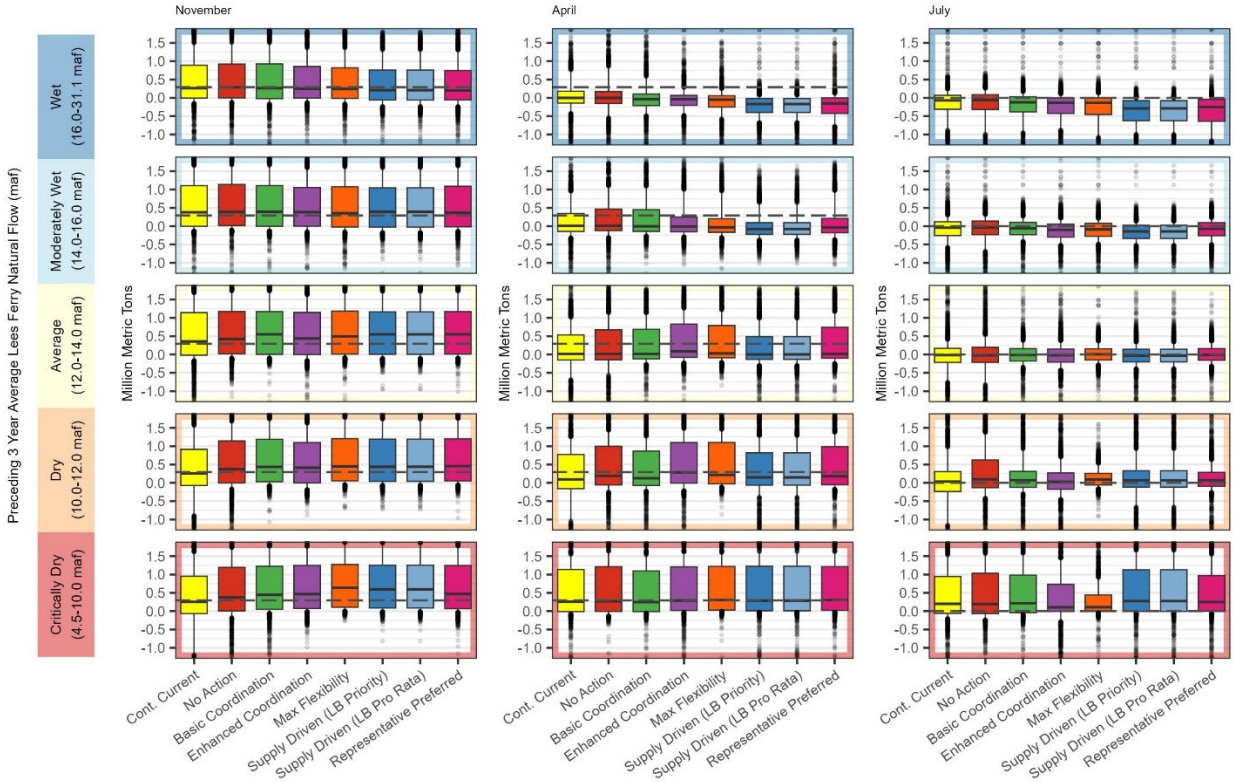


The Representative Preferred Alternative is likely to be vulnerable if the wettest 10-year average Lees Ferry annual flow is 13.8 maf or higher. Compared to the historical periods shown in the Reference Hydrology panel, this flow has occurred before; though, this alternative may or may not be vulnerable in the next 10 years because different aspects of the panel conflict. Considering the Drying with Variability ensemble, about 75 percent of traces are greater than 13.8 maf, suggesting this alternative is reasonably likely to be vulnerable. However, the recently observed 10-year period (of 12.1 maf) is below 13.8 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

All of the alternatives are vulnerable to historical conditions, of which the wettest 10-year period averaged 18.8 maf annually. Four of the alternatives (the CCS Comparative Baseline, No Action, and Supply Driven [both LB Priority and LB Pro Rata approaches] Alternatives) would have been vulnerable during the most recently observed 10-year period (2016-2025), which had an average flow of 12.1 maf.

Figure TA 5-7 shows the distribution of sand accumulation (in millions of metric tons) in Marble Canyon for three time periods: July 1 to November 1, July 1 to April 1, and July 1 to July 1 (the full sediment year, Topping et al. [2000]). Negative values indicate sand depletion. The distributions are further categorized according to five hydrologic conditions based on the average natural flow at Lees Ferry over the preceding 3-year period.

Figure TA 5-7
Marble Canyon Sand Accumulation or Depletion from (left) July 1 to November 1, (middle) July 1 to April 1, and (right) July 1 to July 1



Interpretation of **Figure TA 5-7** depends on the three periods of interest. From July to November, it is preferable for sand accumulation to exceed 294,000 metric tons (indicated by a dashed line in the November column). Since 294,000 metric tons is the average transport capacity for an HFE event of 60 hours, the duration at which successful beach building occurs, sand accumulation exceeding this threshold allows for a fall HFE event (provided enough water is available in Lake Powell). If that is not possible, sand accumulation from July to April exceeding 294,000 metric tons (indicated by a dashed line in the April column) allows for a spring HFE event. In either case, it is preferable for annual sand accumulation from July to July to be near zero (indicated by a dashed line

in the July column), which suggests sand accumulated during the prior sediment year was subsequently depleted via an HFE event.

For all five hydrologic conditions, most sand accumulation in Marble Canyon occurs from July to November, the summer-fall thunderstorm season during which the Paria and Little Colorado Rivers are most active. Slightly less accumulation occurs for the wettest conditions, during which non-HFE releases are more likely to transport sand downstream, while slightly more accumulation occurs for the driest conditions.

In the Moderately Wet and Wet Flow Categories, conditions that would trigger an HFE release (i.e., Marble Canyon sand accumulation exceeding 294,000 metric tons) are more likely to occur in November. From November to April, larger than normal releases outside of HFE events are likely to contribute to sediment depletion, resulting in a median change in sand mass between July and April of close to zero. While very little change in sand mass occurs from April to July, indicating spring HFEs are uncommon during these conditions, slightly more depletion occurs on an annual basis under the Wet Flow Category.

In the Average and Dry Flow Categories, sand is also depleted between November and April, but the decrease is more gradual. As a result, sand accumulation exceeds 294,000 metric tons for a greater percentage of futures from July to April, allowing for spring HFE events. The gradual decrease in sand mass continues from April to July, so that on an annual basis (July 1 to July 1), there is little net change in sand mass, similar to the wettest two categories.

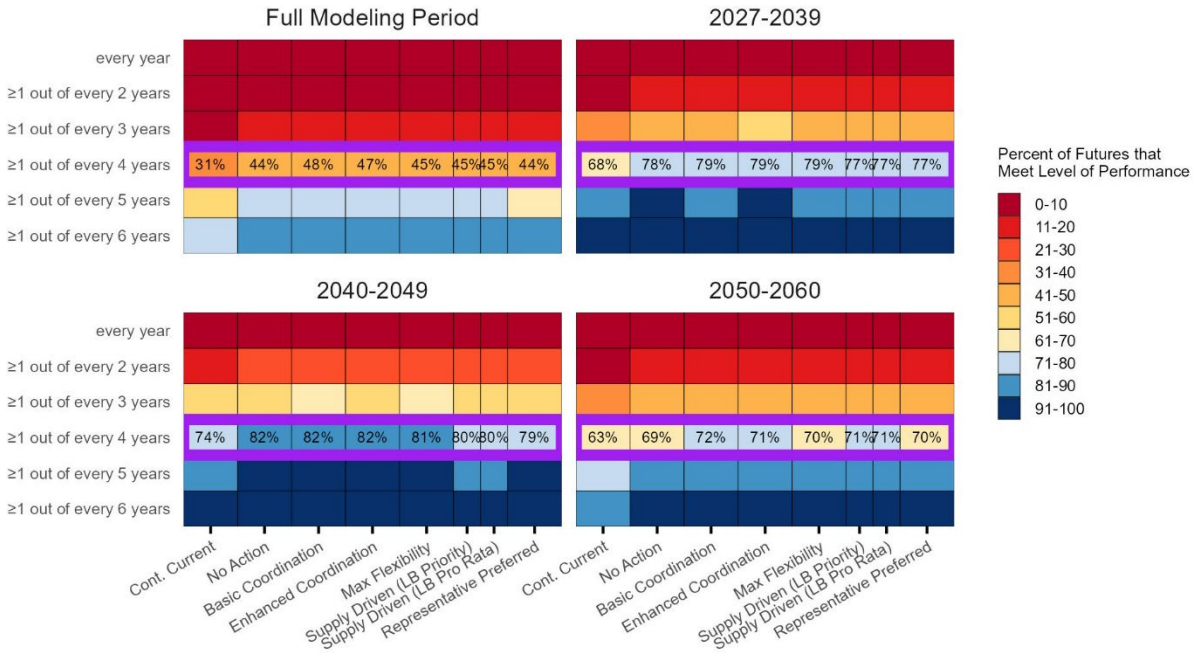
All six alternatives perform comparably across the four flow categories above. Only in the Critically Dry Flow Category does meaningful differentiation exist among performance. In general, there is little change in sand mass from both November to April and April to July, indicating HFE events are infrequent. However, on an annual basis, a smaller level of accumulation occurs for the Maximum Operational Flexibility and (somewhat) Enhanced Coordination Alternatives, suggesting they are slightly more conducive to HFE events during these conditions.

Figure TA 5-8 shows how often Marble Canyon sand mass exceeds 294,000 metric tons, the average transport capacity for a 60-hour HFE, in November or April. A 60-hour duration is required for successful beach building. The highlighted row shows the percentage of futures that meet this condition at least once every 4 years, the preferred minimum performance. As stated in the Methodology (see **TA 5.2.1**, Methodology), each future was randomly assigned a trace of Paria River sediment input (however, each future/sediment trace combination was kept the same across the alternatives).

Aside from the CCS Comparative Baseline, the other alternatives are similarly robust. The percentage of futures in which the November or April sand mass exceeds 294,000 metric tons at least once every 4 years in the other alternatives, ranges from 44 percent to 48 percent for the full modeling period. For the CCS Comparative Baseline, less than a third of the futures in the full modeling period meet the 294,000 metric ton threshold at least once every 4 years. As mentioned earlier for other figures, fewer futures meet the preferred minimum performance over the full modeling period than in any one of the subperiods, a reflection of the increasing difficulty of sustaining this performance level over a longer period and evidence of the interdecadal variability inherent in the ensemble of projected conditions.

Based on the planned length of this decision, it is important to note that, similar to the other action alternatives, the Representative Preferred Alternative meets the preferred minimum performance level in 77 percent of futures in the 2027-2039 modeling period.

Figure TA 5-8
Marble Canyon Sand Mass: Robustness.
Percent of futures in which the Marble Canyon sand mass exceeds 294,000 metric tons in November or April in the frequency of years specified in each row

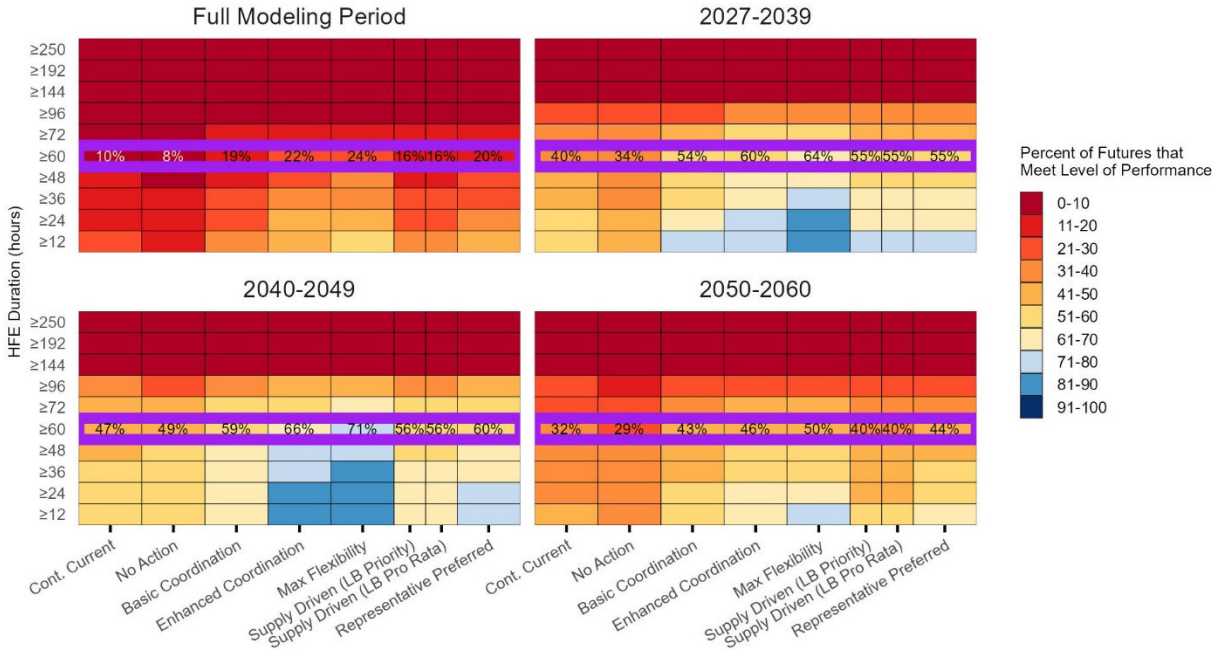


TA 5.2.4 Issue 3: HFE Frequency and Duration

Water availability in, and water releases from, Lake Powell can have an impact on HFE scheduling. Large non-HFE releases, such as the equalization flows implemented in 2011 to balance storage between Lake Powell and Lake Mead (Hazel et al. 2022), can reduce the sand mass in Marble Canyon available for an HFE without providing the benefit of increasing sandbar volumes further downstream (Grams et al. 2025; Topping et al. 2021; Salter et al. 2025). Since the alternatives propose different ways of operating Glen Canyon Dam, they have different impacts on water availability in Lake Powell, and consequently, the scheduling of HFE releases. Grams et al. (2025) noted that, except for the HFE implemented on March 26, 1996, the durations for all HFEs implemented have been between 60 and 96 hours.

Figure TA 5-9 shows the percentage of futures in which the annual HFE duration equals the number of hours specified in each row at least once every 4 years. Futures are considered preferable at a duration of 60 hours, the minimum duration associated with significant sandbar deposition. The highlighted row provides the percentage of futures that meet this criterion.

Figure TA 5-9
Annual HFE Duration: Robustness.
Percent of futures in which the annual HFE duration is the number of hours specified in each row at least once every 4 years



For the full modeling period, none of the alternatives satisfy the preferred minimum performance in more than 24 percent of futures. Fewer futures meet the preferred minimum performance over the full modeling period than in any one of the subperiods, a reflection of the increasing difficulty of sustaining this performance level over a longer period and evidence of the interdecadal variability inherent in the ensemble of projected conditions. For all periods, the action alternatives are similarly robust and perform better than the CCS Comparative Baseline and No Action Alternative, with the Maximum Operational Flexibility Alternative performing slightly better than the others. It is important to note the modeling does not imply an expected outcome, just that HFEs remain possible. HFE triggers and final HFE implementation would be a result of the LTEMP process.

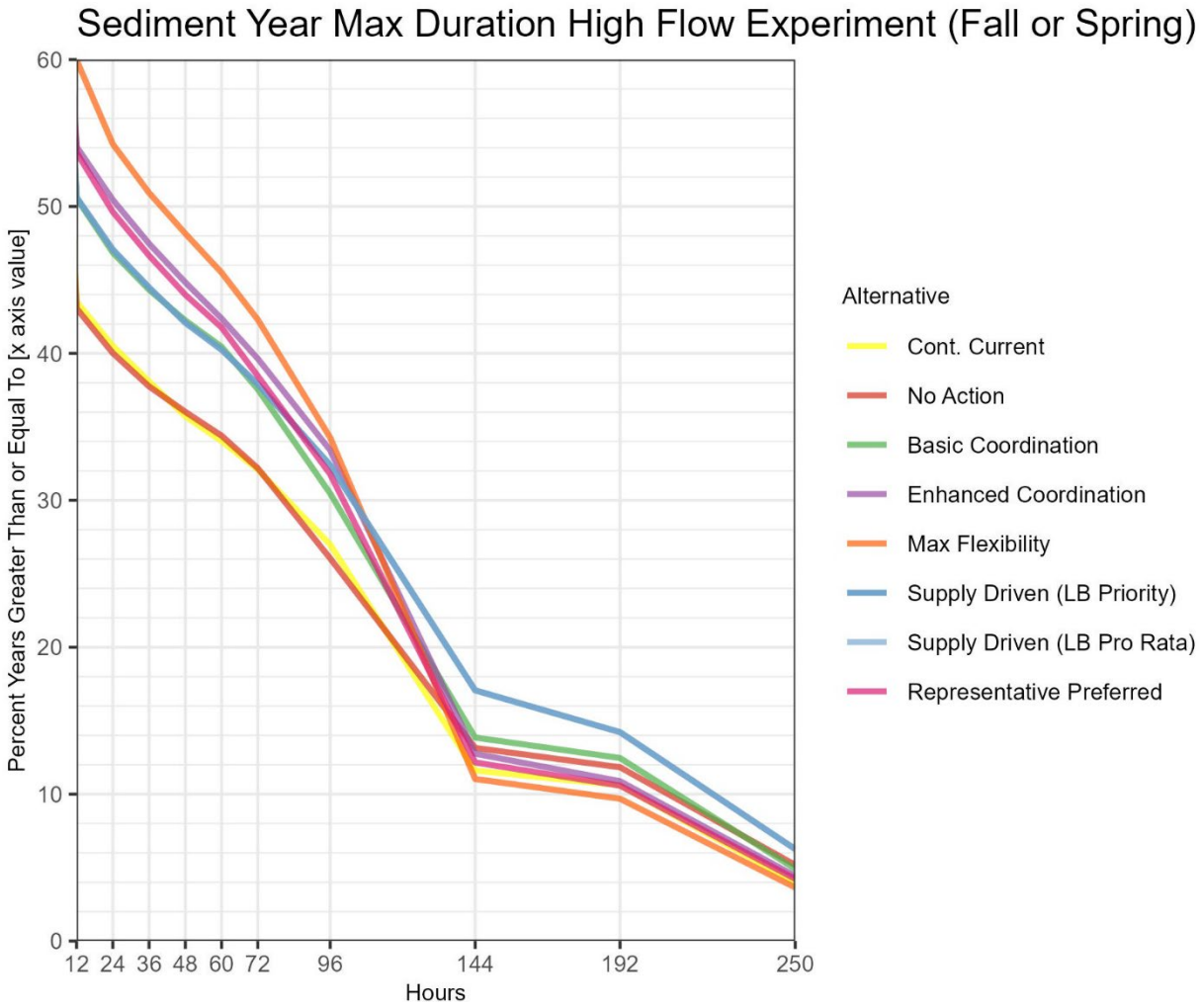
Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Representative Preferred Alternative meets the preferred minimum performance level in 55 percent of future which is the same as the Supply Driven Alternative (both LB Priority and Pro Rata approaches) and similar to the Basic Coordination Alternative (54 percent). The Maximum Operational Flexibility (64 percent) and Enhanced Coordination (60 percent) Alternatives are more robust. The No Action Alternative (34 percent) and CCS Comparative Baseline (40 percent) meet the preferred minimum performance least often in the first decade.

Figure TA 5-10 shows the frequency of HFE releases as a function of HFE duration, represented as the percentage of simulated years in which an HFE of a specified duration occurs. An HFE of 60 hours or longer occurring at least once every 4 years is the preferred minimum performance. While

Figure TA 5-10 does not directly address this indicator, it suggests the likelihood with which it is met.

For HFE releases lasting 12 to 96 hours, the Maximum Operational Flexibility, Enhanced Coordination, and Representative Preferred Alternatives perform the best, with 46, 43, and 42 percent of years having HFE releases greater than or equal to 60 hours, respectively. For HFE releases greater than or equal to 96 hours, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs better than the other alternatives. Below 60 hours, the performance of the Basic Coordination Alternative is generally comparable to that of the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and lower than the other action alternatives.

Figure TA 5-10
Frequency of HFE Releases as a Function of HFE Duration



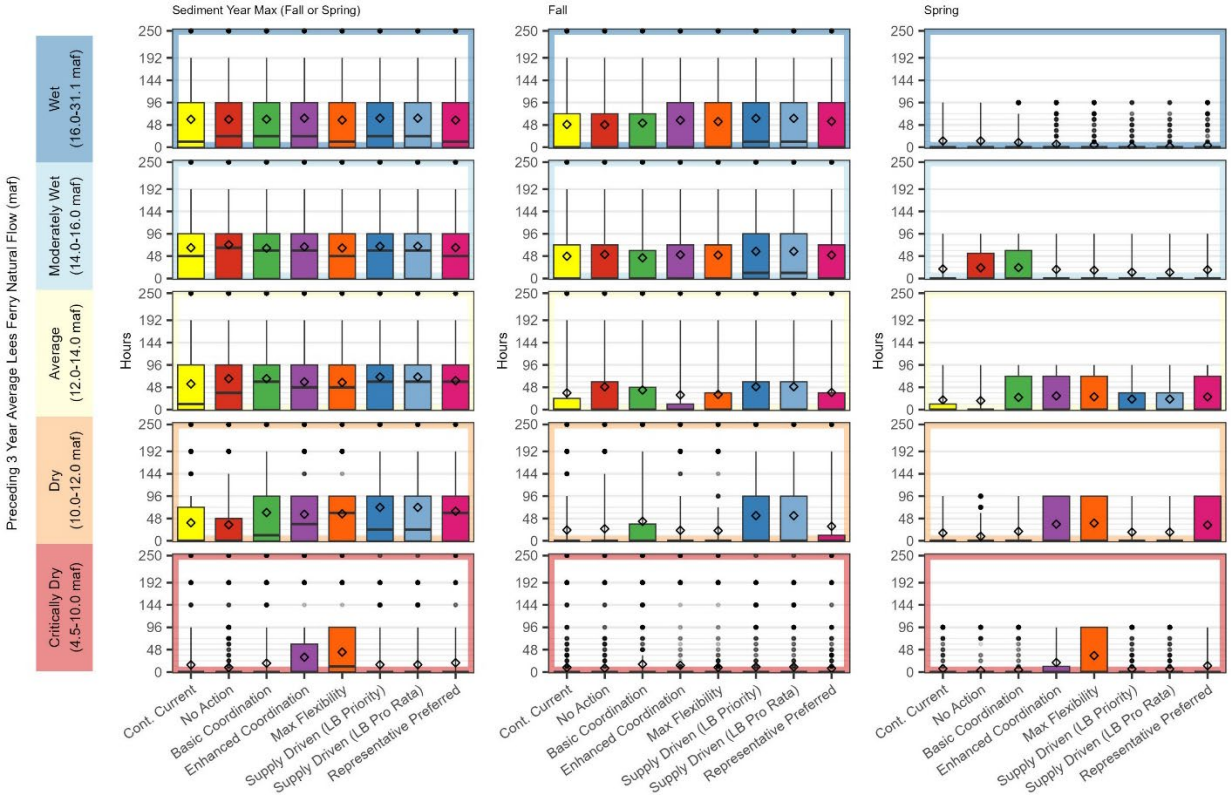
The worst performance generally occurs under the CCS Comparative Baseline and the No Action Alternative. Their performance is comparable for HFE durations below 144 hours. For HFE durations above 144 hours, the No Action Alternative performs slightly better than the CCS

Comparative Baseline. However, excluding the HFE implemented on March 26, 1996, HFE durations above 144 hours have not been implemented (Grams et al. 2025).

While **Figure TA 5-10** indicates that, across all alternatives, 60-hour HFEs would occur in 36 to 46 percent of years simulated, **Figure TA 5-9** indicates 60-hour HFEs every 4 years would occur in only 10 to 25 percent of futures. This suggests that many more futures have HFEs concentrated over a small time period than futures in which HFEs are evenly spread out, another reflection of the importance of interdecadal hydrologic variability.

Figure TA 5-11 shows the distribution of HFE durations for the full sediment year (July 1 to July 1), fall, and spring. The distributions are further categorized according to five hydrologic conditions based on the average natural flow at Lees Ferry over the preceding 3-year period. As stated above, the preferred minimum performance is an HFE lasting 60 hours or longer at least once every 4 years. The Methodology (see **TA 5.2.1**) indicates that for an HFE to be scheduled, enough sand must be available in Marble Canyon, and enough water must be available in Lake Powell. If enough sand and water are available, longer HFE's could be scheduled. While **Figure TA 5-11** does not directly address this indicator, it provides some indication of the likelihood with which it is met.

Figure TA 5-11
Annual Duration of HFE Releases



The performance of alternatives in **Figure TA 5-11** varies by flow category. For the two wettest categories, the distribution of annual HFE durations over the full sediment year is comparable across all alternatives, with the majority of HFEs occurring in the fall. For the Average Flow

Category, HFE durations over the full sediment year are again comparable, but the timing of HFEs for the Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives begins to shift from fall to spring. This trend continues for the two driest flow categories, with only the Enhanced Coordination and Maximum Operational Flexibility Alternatives resulting in HFEs of any significant duration in the Critically Dry Flow Category, typically occurring in the spring.

Notably, for all alternatives in all flow categories, the 75th percentile of HFE durations for the full sediment year is typically higher than it is in either fall or spring. This is due to the larger sample size of fall HFEs, whose high outliers serve to increase the 75th percentile for the full sediment year.

TA 5.2.5 Issue 4: Sandbar Volume

The sandbar volume above the water level during a 25,000 cfs flow condition, the threshold above which camping and recreational activities are considered safe, represents the volume of "usable" sand in the canyon. In general, larger sandbar volumes are preferable over smaller sandbar volumes.

Figure TA 5-12 shows distributions of "usable" sandbar volume, further categorized according to five hydrologic conditions based on the average natural flow at Lees Ferry over the preceding 3-year period. As the preferred minimum performance, sandbar volumes should exceed their volume at the start of the simulation period for at least 60 percent of modeled years. The average sandbar volume for the 25 sandbar monitoring sites at the start of the simulation period is 1169.512 cubic meters, indicated by a dashed horizontal line.

For all but the Wet Flow Category, all alternatives show sandbar growth in greater than 60 percent of years, with nearly all alternatives showing sandbar growth in greater than 75 percent of years. For the Wet Flow Category, the Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives show sandbar growth in greater than 60 percent of years, and 25th percentile sandbar volumes for all alternatives are lower than the initial condition (1169.512 cubic meters on average for the 25 sandbar monitoring sites). In general, sandbar growth increases as hydrologic conditions become drier. Differences in performance among the alternatives also increase as hydrologic conditions become drier, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives clearly performing the best for the Critically Dry Flow Category.

Figure TA 5-13 shows the percentage of futures with *net* sandbar growth by comparing the maximum sandbar volume for each year with the volume at the start of each of four periods (2027–2039, 2040–2049, 2050–2060, and 2027–2060). Here again, the average sandbar volume for the 25 sandbar monitoring sites at the start of the full simulation period (2027) is 1169.512 cubic meters; initial sandbar volumes for subperiods depend on the hydrology trace. It is important to note that **Figure TA 5-13** does not show the percentage of years with year-over-year sandbar growth; if large increases in sandbar volume occur at the start of a period, it is very possible for sandbar volume to be lower than it was the year before and still be higher than it was at the start of the period. The figure reflects an alternative's ability to achieve long-term sandbar growth over scales of decades or more.

Figure TA 5-12
Sandbar volume above the water level associated with a flow rate of 25,000 cfs

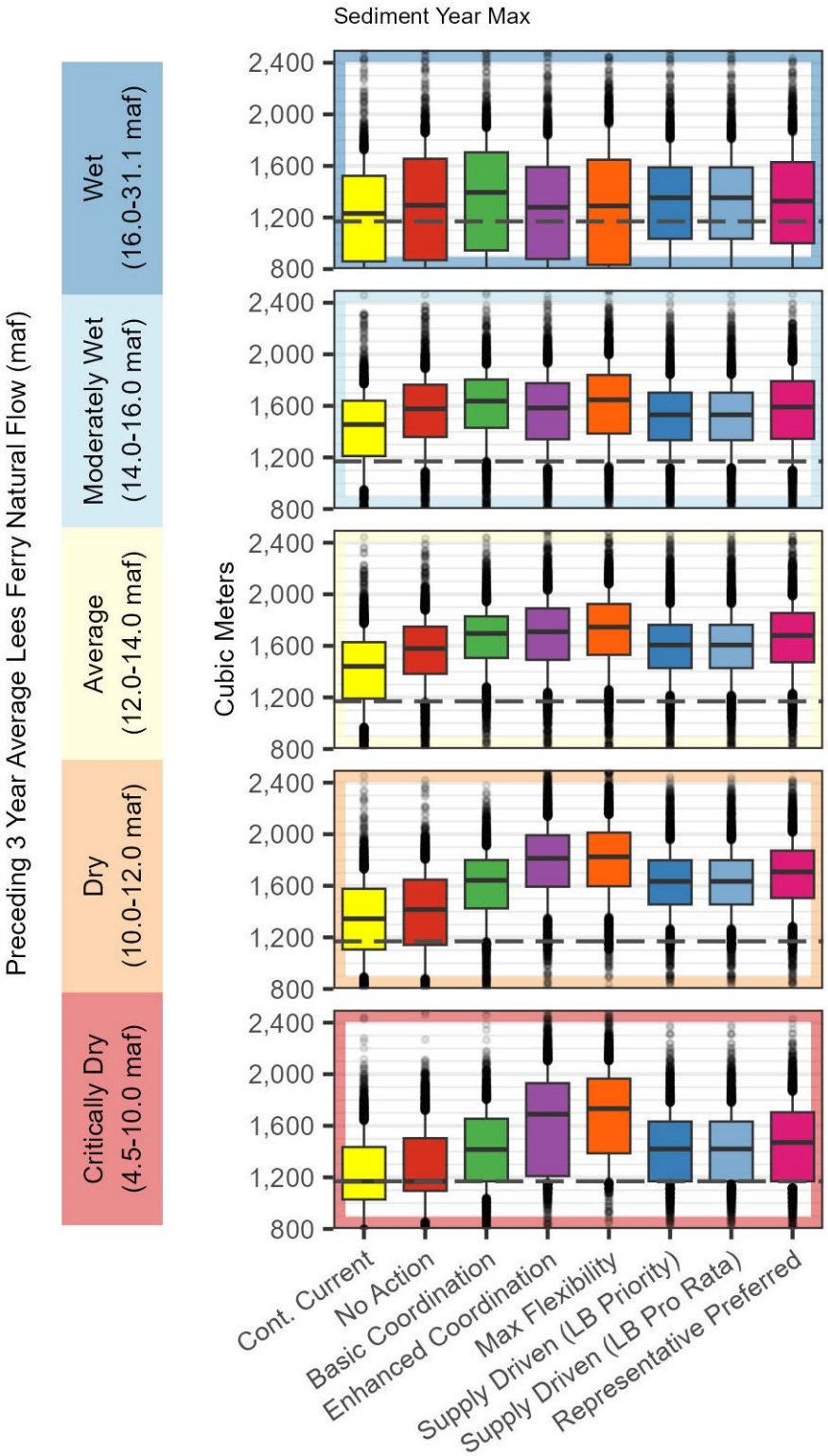
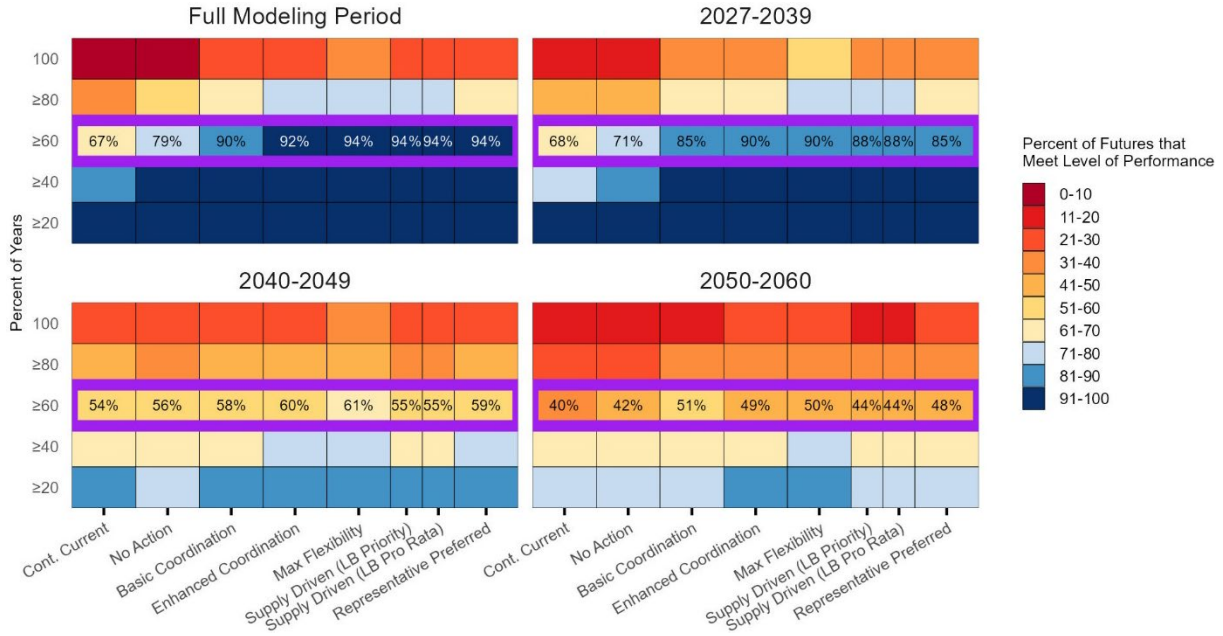


Figure TA 5-13
Long-Term Sandbar Growth: Robustness.
Percent of futures in which the weighted average sandbar volume of Grand Canyon and Marble canyon has increased relative to the start of each period in the percent of years specified in each row



A future is considered to satisfy the minimum preferred performance level if at least 60 percent of years within a given period have a sandbar volume that is larger than the sandbar volume at the start of the given period. The highlighted row provides the percentage of futures that meet this criterion.

Over the full modeling period, the Maximum Operational Flexibility, Enhanced Coordination, Supply Driven (both Priority and Pro Rata approaches), and Representative Preferred Alternatives are truly robust, meeting the minimum preferred performance level in over 90 percent of years. Though slightly less, the Basic Coordination Alternative is similarly robust, meeting the minimum preferred performance level in 90 percent of years. Performance level is lowest for the No Action Alternative and CCS Comparative Baseline, with the latter being the least robust. Most of the increase occurs in the first 13-year period, after which sandbar growth slows, possibly because of the larger sandbar volumes, and fewer opportunities for deposition, at the start of the other subperiods.

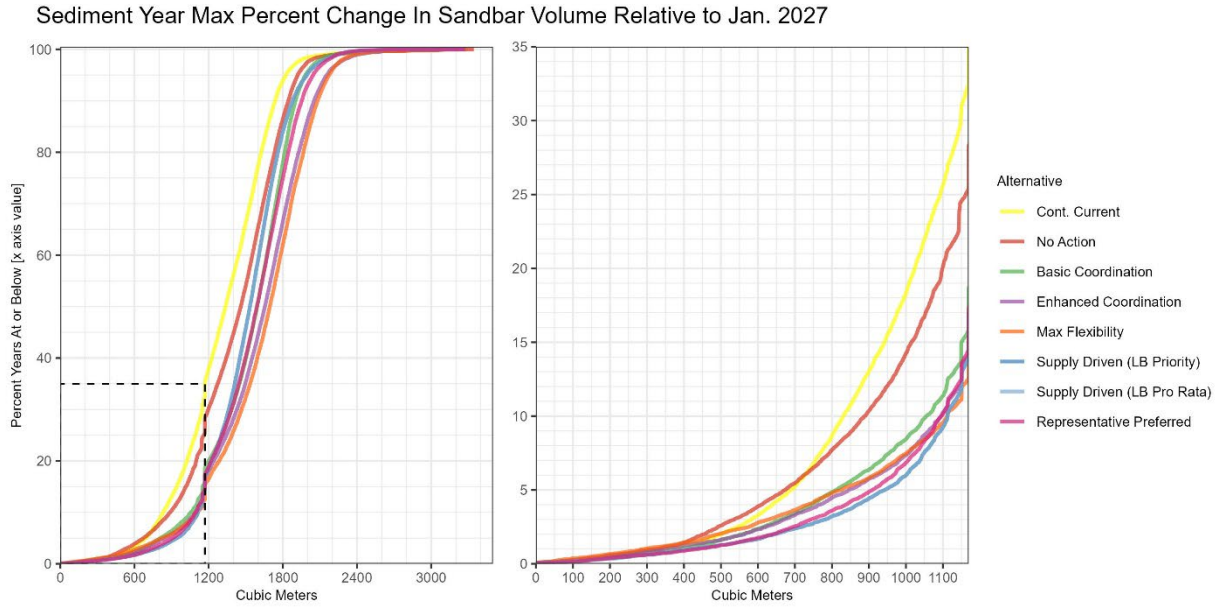
In general, a relatively high percentage of futures (at least 90 percent for all five action alternatives) meet the preferred minimum performance of more than 60 percent of years with net sandbar growth. This contrasts with figures such as **Figure TA 5-9**, where no more than 24 percent of futures meet the preferred minimum performance of 60-hour HFEs at least once every 4 years. The discrepancy is due to the definition of sandbar growth with respect to the *beginning* of a period, which allows for the possibility that years without an HFE might still meet this preferred minimum performance. In addition, each future is based on a single simulation and consequently subdivided into the three modeling subperiods. Consequently, the initial conditions for the 2040–2049 and 2050–2060 modeling periods depend on the simulation and differ for each future. The significant

increase in sandbar volume during the 2027–2039 modeling period could be partially attributed to the modeling assumption that HFEs are implemented as often as possible (see **TA 5.2.1**, Methodology).

Based on the planned length of this decision, it is important to note that, similar to the other action alternatives, the Representative Preferred Alternative meets the preferred minimum performance level in 85 percent of futures in the 2027-2039 modeling period. The CCS Comparative Baseline (68 percent) and No Action Alternative (71 percent) are less robust over the first modeling period.

Figure TA 5-14 shows the percentage of simulated years for which the maximum sandbar volume is less than or equal to a given value. A lower percentage of years for which sandbar volume is below a given value corresponds to a greater percentage of years for which sandbar volume is above that value. Therefore, curves with lower placement in the plot imply better performance for that alternative. The average sandbar volume for the 25 sandbar monitoring sites at the start of the full modeling period is 1169.512 cubic meters (see **TA 5.2.1**, Methodology).

Figure TA 5-14
Percentage of Years for which Maximum Sandbar Volume is at or below Given Values



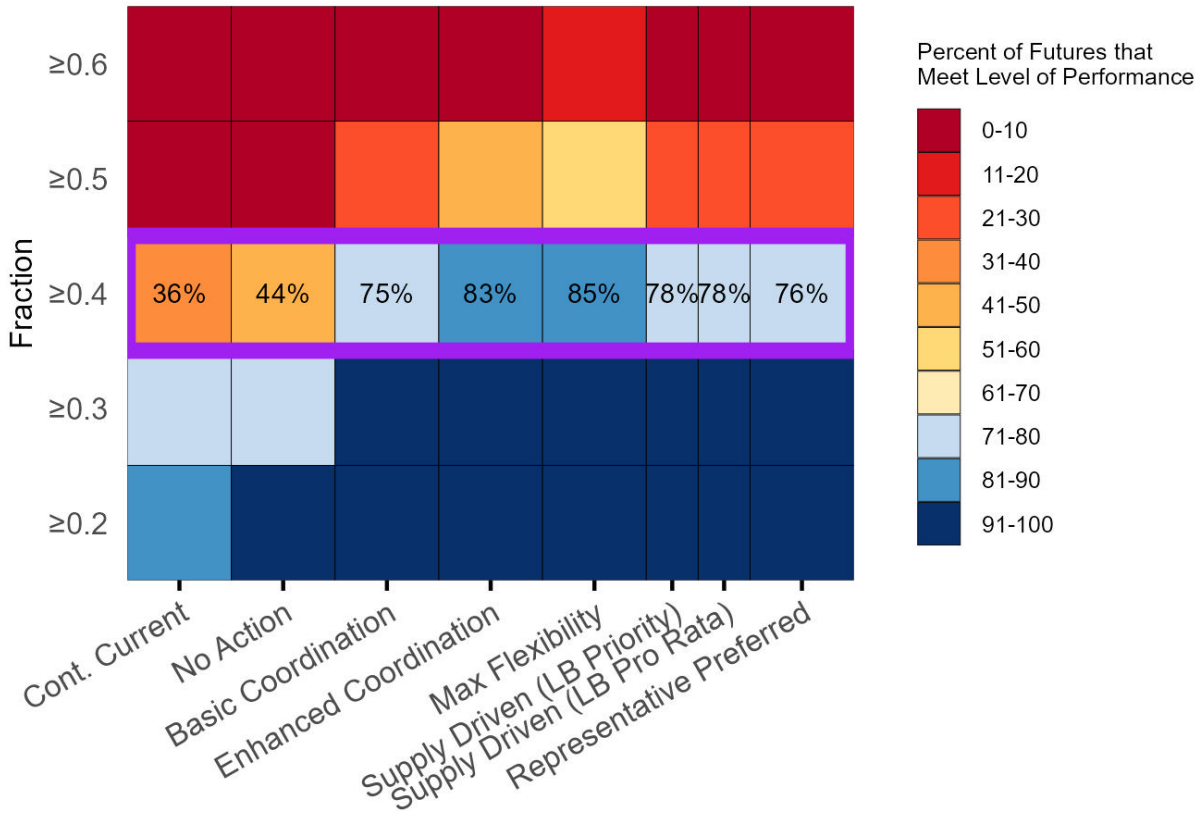
With respect to the initial condition, the five action alternatives perform comparably, all resulting in average sandbar volumes smaller than 1169.512 cubic meters 13 to 15 percent of the time for the 25 sandbar monitoring locations. For very small sandbar volumes (less than 1000 cubic meters), the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs slightly better than the others. Performance under No Action lags behind, with performance for the CCS Comparative Baseline ranking last.

TA 5.2.6 Issue 5: Sand Transport

While sand can be transported downstream with flows well below 37,000 cfs, lower flows are not as conducive to sandbar formation and retention. The higher the fraction of sand transported during the larger flow events (above 37,000 cfs), the more sand that is available for sandbar formation (Hazel et al. 2022; Salter et al. 2025).

Figure TA 5-15 shows the percentage of futures in which the total sand mass transported by flow rates above 37,000 cfs (sandbar-forming flow rates) exceeds a given fraction over the 34-year simulation period. A future is considered to meet the minimum preferred performance level if the fraction of sand mass transported by sandbar-forming flow rates is at least 0.4 (40 percent of the sand transport). The highlighted row provides the percentage of futures that meet this criterion.

Figure TA 5-15
Sand Load Index: Robustness.
Percent of futures in which the sand mass transported when flows are above 37,000 cfs is at least the fraction specified in each row of the total sand mass transported over the 34-year modeling period



Under the best performing alternatives, the Maximum Operational Flexibility and Enhanced Coordination, 85 and 83 percent of simulated futures, respectively, meet the minimum preferred performance level, i.e., at least 40 percent of sand mass is transported by sandbar-forming flow rates in 85 and 83 percent of simulated futures, respectively. The next best performance occurs under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), for which 78 percent of

futures meet the preferred minimum performance, followed by the similarly robust Representative Preferred and Basic Coordination Alternatives, for which 76 and 75 percent of futures meet the preferred minimum performance, respectively. Under both the No Action Alternative and the CCS Comparative Baseline, at least 40 percent of sand mass is transported by sandbar-forming flow rates in less than half of the simulated futures, with the CCS Comparative Baseline performing the worst of all alternatives.

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Technical Appendix 6

Water Quality

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
°C	degrees Celsius
°F	degrees Fahrenheit
Basin	Colorado River Basin
CCS	Continued Current Strategies
CRSS	Colorado River Simulation System
DMDU	Decision Making under Deep Uncertainty
EPA	United States Environmental Protection Agency
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
Mexico	United Mexican States
mg/L	milligrams per liter
PFAS	per- and polyfluoroalkyl substances
Reclamation	Bureau of Reclamation
TDS	total dissolved solids
U.S.	United States
USGS	United States Geological Survey
WY	water year

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TA 6. Water Quality

TA 6.1 Affected Environment

This section describes selected water quality constituents that could be affected by the alternatives. These water quality constituents of concern are:

- Salinity
- Temperature
- Harmful algal blooms and nutrients
- Dissolved oxygen
- Metals
- Perchlorate
- Per- and polyfluoroalkyl substances (PFAS)

Other water quality issues were considered but are not discussed here, as they were unlikely to be affected by the alternatives or lacked sufficient data for assessment.

TA 6.1.1 Salinity

Historically, elevated salinity levels have been a concern for the Colorado River Basin (Basin), as higher salinity concentrations cause economic damage across agricultural, municipal, and industrial sectors in the United States (U.S.), and negatively impact municipal and agricultural users in the United Mexican States (Mexico; USGS 2021). To address these issues, in 1974 Congress enacted the Colorado River Basin Salinity Control Act, which directed the Secretary of the Interior to proceed with a program to enhance and protect the quality of water available in the Colorado River for use in the U.S. and Mexico. In 1975, the U.S. Environmental Protection Agency (EPA) approved water quality standards developed by the seven Basin States in response to the Federal Water Pollution Control Act of 1972. The standards included numeric criteria for three stations on the mainstem of the lower Colorado River (below Hoover Dam, below Parker Dam, and at Imperial Dam) and a Plan of Implementation to control salinity increases.

The Colorado River Basin Salinity Control Forum continues to review and make salinity criteria recommendations for the Colorado River every 3 years (Colorado River Basin Salinity Control Forum 2023). The water quality standards for salinity in the Colorado River were approved by the EPA and are reviewed every three years pursuant to Section 303(c)(1) of the Clean Water Act. **Table TA 6-1** shows the current salinity criteria for the Colorado River.

Table TA 6-1
Salinity Criteria for the Colorado River

Station	Flow-weighted average annual salinity (milligrams per liter [mg/L])
Below Hoover Dam	723
Below Parker Dam	747
At Imperial Dam	879

Source: Colorado River Basin Salinity Control Forum 2023

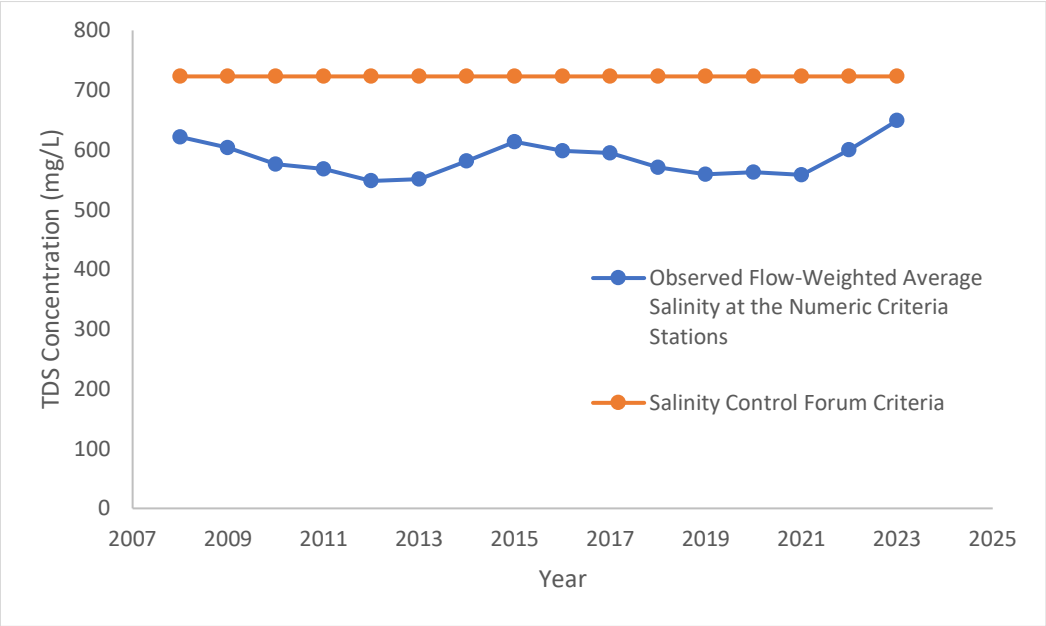
Salinity control is accomplished through multiple programs. The U.S. Department of Agriculture's Environmental Quality Incentives Program provides cost-share assistance to landowners who install salinity control measures (Reclamation 2022). Additionally, federal agencies, including the Bureau of Reclamation (Reclamation), the Bureau of Land Management, and the U.S. Department of Agriculture, pursue improvements on federal lands to reduce salinity loading to the Colorado River. Despite these efforts, salinity trends have plateaued since 2000, after decreasing throughout the twentieth century (Rumsey et al. 2021). Total dissolved solids[1] (TDS) loads increase during wet periods and decrease during dry periods, so increased regional aridification may be contributing to decreasing stream salinity through quicker surface runoff and lagged groundwater storage processes (Miller et al. 2024; Brooks et al. 2025). Conversely, increased aridification may increase concentrations, as 89 percent of TDS loads are derived from the baseflow fraction of streamflow, and declines in surface runoff are expected to outpace changes in baseflow contributions to streamflow (Rumsey et al. 2017).

Since the construction of Glen Canyon Dam, annual salinity concentration downstream of Glen Canyon Dam varies between 400 and 600 mg/L (Richards 2025). Within Lake Powell, reservoir stratification results in different salinity concentrations at different depths. Releases from lower elevations in Lake Powell through the river outlet works are generally more saline compared with releases from higher elevations through the penstocks of Glen Canyon Dam (Reclamation 2016). See **TA 6.1.2** for a more complete discussion of reservoir stratification.

In a review of sampling efforts from 2007–2023, Reclamation has not exceeded the salinity criteria for the Colorado River, which are described in **Table TA 6-1**. See **Figure TA 6-1**, **Figure TA 6-2**, and **Figure TA 6-3** for more information and historical salinity concentrations in the Lower Basin. Salinity concentrations are based on TDS concentrations and are used interchangeably in this discussion.

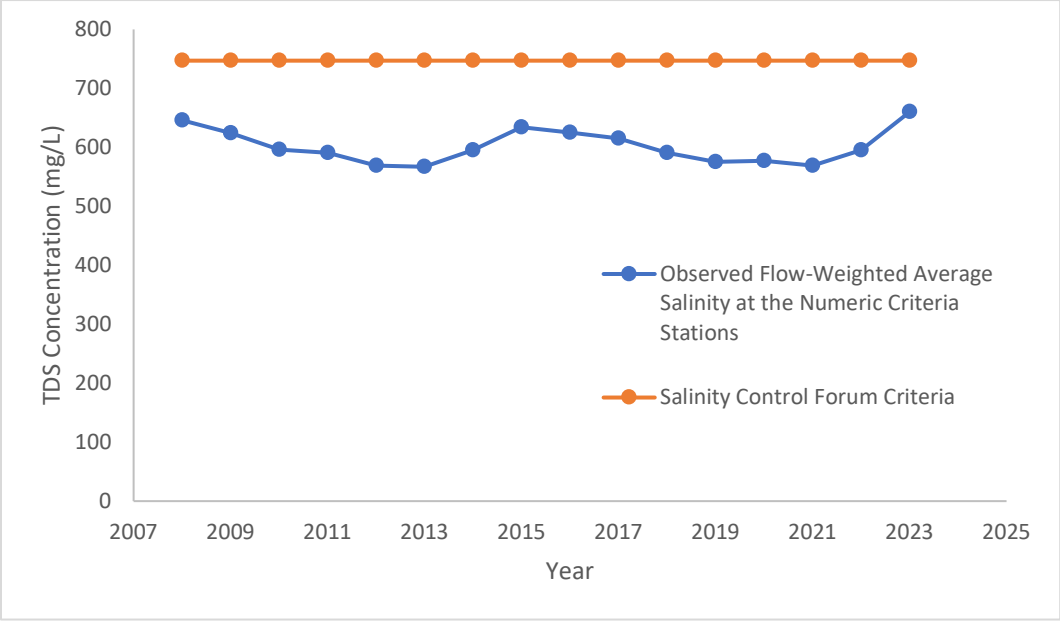
[1] Total dissolved solids are the combined content of all substances in a liquid volume and is related to salinity, which is the total concentration of all dissolved salts in water. The sum of constituents consists of calcium, magnesium, sodium, chloride, sulfate, the carbonate equivalent of alkalinity and, if measured, silica and potassium. The two terms are often used interchangeably in Colorado River salinity discussions.

Figure TA 6-1
Colorado River Salinity Concentrations and Flows Downstream of Hoover Dam
2008–2023



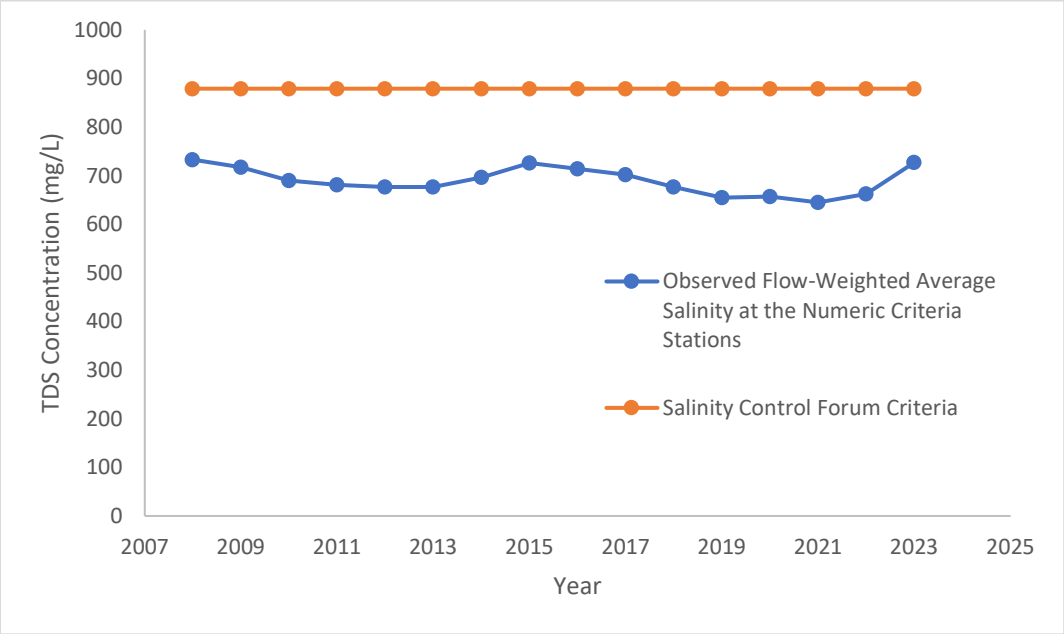
Source: Richards 2025

Figure TA 6-2
Colorado River Salinity Concentrations and Flows Downstream of Parker Dam
2008–2023



Source: Richards 2025

Figure TA 6-3
Colorado River Salinity Concentrations and Flows at Imperial Dam 2008–2023



Source: Richards 2025

TA 6.1.2 Temperature

Lake Powell is a monomictic[2] reservoir with strong thermal stratification through much of the spring, summer, and early fall; this means Lake Powell is arranged into layers with distinct temperatures and chemical characteristics. Generally, Lake Powell's epilimnion, or uppermost layer, ranges from 25 to 30 degrees Celsius (°C; 77 to 86 degrees Fahrenheit [°F]) in the summer, dropping to 6 to 10 °C (42.8 to 50 °F) in the winter (Deemer et al. 2023). Lake Powell's hypolimnion, or deeper layer, ranges from 6 to 9 °C (42.8 to 48.2 °F) year round. In the winter, the thermal stratification breaks down and Lake Powell experiences turnover where the different layers mix to create relatively uniform conditions throughout the water column (Reclamation 2016). Historically, complete mixing of the water column was rare; however, homogenous conditions have been observed more recently with lower reservoir elevations.

Since the early 2000s, lower water levels in Lake Powell have led to warm summer temperatures in the Colorado River below Glen Canyon Dam (Reclamation 2016). Temperatures in the Colorado River in the Grand Canyon are highly variable over space and time and are primarily controlled by the discharge and temperature released from Glen Canyon Dam and solar radiation dynamics along the river corridor (Mihalevich et al. 2020). As water moves farther away from Glen Canyon Dam, the influence of release volume and temperature on water temperature becomes less, and local meteorological conditions become more influential. During summer periods, increases in water temperatures downstream of Glen Canyon Dam are attributed to solar radiation and air temperatures (Dibble et al. 2021). The water in the Colorado River generally warms 1 °C (1.8 °F) for every 30 miles traveled downstream during warmer months of the year under specific discharge and

[2] Monomictic water bodies are those mix completely during one mixing period each year.

meteorological conditions. Some variation in lateral warming also occurs, with warmer temperatures along the shoreline and cooler water in the deep, fast-moving areas (Reclamation 2016).

Lake Mead is also monomictic. Lake Mead inflow temperatures are a function of Glen Canyon Dam discharges and downstream weather conditions (Reclamation 2016). Lake Mead's hypolimnion is around 12 °C (53.6 °F) year-round, and its epilimnion ranges from about 14 to 29 °C (57.2 to 84.2 °F) in the spring, summer, and early fall, dropping to about 13 to 15 °C (55.4 to 59 °F) in the winter (SNWA 2023). During the winter months, Lake Mead experiences turnover in about 50 percent of years. With lower reservoir elevations and increased air temperatures, water temperatures have been increasing, leading to warmer releases from Lake Mead. Further declines in reservoir elevation, coupled with rising air temperatures, may continue to lead to warmer releases from Lake Mead, though this depends on whether the lower Hoover Dam outlet is used (Hannoun et al. 2022).

TA 6.1.3 Harmful Algal Blooms and Nutrients

Nutrients, such as nitrogen and phosphorus, are essential for plant and animal growth and nourishment, but the overabundance of certain nutrients in water can harm human health, affect ecosystems, and impact recreational opportunities (USGS 2019; NPS 2025). Excess nutrients can cause eutrophication, where the accumulation of nutrients in a body of water results in the increased growth of microorganisms, such as algae. Algae can rapidly increase, leading to algal blooms, characterized by unsightly scum on the water surface, and producing toxins that pose serious health risks to humans and animals (NPS 2025). Consumption of dead algae by bacteria consumes dissolved oxygen and may deplete the oxygen in the water column, leading to fish kills (USGS 2019). For more details on the impacts of dissolved oxygen levels in the water column, see **TA 6.1.4**.

The most severe algal blooms are caused by cyanobacteria and have the potential for production of toxins that can threaten drinking water quality and harm human health (USGS 2019). Certain toxins, such as Microcystin-LR cylindrospermopsin, are associated with symptoms such as abdominal pain, headache, and vomiting, while the Anatoxin-a group toxin can lead to symptoms such as tingling, burning, numbness, drowsiness, and respiratory paralysis (EPA 2014). Algal blooms have led to water advisories at recreational sites within the planning area, such as the Glen Canyon National Recreation Area. When the National Park Service detected cyanotoxins at the Glen Canyon National Recreation Area, they recommended that boaters use caution and avoid unnecessary exposure to the reservoir for recreational activities such as fishing and boating (NPS 2025). See **TA 14.1.1**, Shoreline Public Use, **TA 14**, Recreation, for additional information on recreational activities.

Higher water temperature can elevate eutrophic conditions by stimulating nutrient release from lake sediments, increasing the rate of bacterial activity, and more easily converting nutrients into forms used by algae (Havens 2012; Wang et al. 2023). In Lake Mead in 2015, increased inflow temperature contributed to a harmful algal bloom caused by the freshwater cyanobacteria, *Microcystis*, which can produce toxins harmful to humans, pets, and wildlife (Reclamation 2016).

Releases from Glen Canyon Dam and downstream Colorado River waters are generally low in nutrients (for example, the Glen Canyon Dam phosphorus releases average 0.005 mg/L; Deemer et al. 2023). Tributary inflows (for example, Paria River and Little Colorado River) typically contain

higher levels of nutrients than the mainstem Colorado River (Reclamation 2016), but overall appear to contribute relatively little to overall nutrient concentrations.

In Lake Mead, water within Las Vegas Bay has the highest concentration of nutrients due to the discharges of highly treated wastewater from the Las Vegas metropolitan area. Wastewater is a persistent contributor of phosphorus, whereas stormwater with higher phosphorus contributions is an acute contributor but a minor source overall given the infrequency of storm events. Since phosphorus is a limiting nutrient in the Colorado River system, these contributions support algal growth (USGS 2012). Lowering reservoir levels could increase the concentration of nutrients and temperatures, especially in shallow areas, which could be more favorable for algal growth (Hannoun et al. 2022).

Lake Powell is a low nutrient, oligotrophic[3] waterbody. Preliminary analyses of long-term trends in limnological data reveal a directional change in several parameters in Lake Powell in recent decades (Deemer et al. 2023). These initial data analyses suggest an increase in surface phytoplankton biovolume (algal biomass) that may be paired with changes in community composition and could have cascading effects on ecosystem function and water quality management. For example, cyanobacteria genera across all sites have appeared to shift considerably from the beginning of monitoring (1993–1997) compared to recent years (2017–2021). These community shifts could translate into changes in algal toxin formation and/or altered edibility for aquatic grazers. Growing occurrences of harmful algal blooms in Lake Powell could mean critical changes to Lake Powell water quality with detrimental results to human use and aquatic life. In a mixed methods literature review of assessing risk for cyanobacteria and phytoplankton with changes in water level regime, cyanobacteria were significantly more likely to increase in response to decreases in water levels. The review also suggested that the prevalence of cyanobacteria increases when reservoir water levels decline, subsequently increasing the risk of cyanobacterial blooms in reservoirs undergoing more severe water level fluctuations and/or declines (Hoffman et al. 2025). See **TA 8.1.3***, Reaches*, in **TA 8**, Biological Resources – Fish and Other Aquatic Species, and **TA 14.1.1***, Shoreline Public Use*, in **TA 14**, Recreation, for additional information about harmful algal blooms' impacts on aquatic species and recreation.

TA 6.1.4 Dissolved Oxygen

Dissolved oxygen is a critical factor for fish health. Research on dissolved oxygen thresholds for both warmwater and coldwater fish species shows that salmonids are particularly vulnerable to low dissolved oxygen concentrations compared to warmwater species (Saari et al. 2018). Sustained dissolved oxygen levels below 3 mg/L can significantly reduce survival rates and feeding efficiency, whereas concentrations in the range of 6–9 mg/L are considered optimal for growth and survival across all life stages (EPA 1986).

Generally, Lake Powell dissolved oxygen concentrations are at their highest in the spring to early summer, when inflows are well-oxygenated and wind-induced mixing is high. Low dissolved oxygen concentrations move through the reservoir and closer to the dam during the summer into the fall because of organic matter decomposition and chemical reactions that consume oxygen. Dissolved

[3] Oligotrophic waterbodies are those with low concentrations of nutrients.

oxygen gradually increases in the winter because of the higher oxygen-carrying capacity of cold water and the natural mixing processes that occur during turnover. When water is discharged through the river outlet works, it becomes well-aerated and increases the dissolved oxygen levels in the tailwaters but only while the river outlet works are open.

Recently, dissolved oxygen levels in Lake Powell and the Glen Canyon Dam tailwaters[4] have been low compared with historical dissolved oxygen levels. This is due to a combination of low reservoir elevations and increasing reservoir age (Deemer et al. 2025). Low dissolved oxygen plumes occur in response to large sediment inputs; this is because suspended sediment creates high biological and chemical oxygen demand (that is, bacteria and other biota consuming oxygen, and chemical reactions consuming oxygen). Monsoonal activity, typically between July and September, can discharge particularly high organic matter loads from tributaries, leading to elevated oxygen demand within the reservoir. Large spring snowmelt inflows to Lake Powell can further drive down dissolved oxygen concentrations by resuspending deltaic sediments. Near the Colorado River inflow, approximately 45 meters (150 feet) of sediment has accumulated over the life of the reservoir. With lower storage conditions, the Colorado River has been carving away this sediment and creating a new path through its delta.

Low dissolved oxygen plumes can often extend the entire length of the reservoir, typically in the metalimnion due to the prevalence of interflows (Colorado River inflows denser than the surface water of Lake Powell entering the reservoir at a depth of neutral buoyancy). With lower storage conditions, penstock intakes draw from the metalimnion layer more frequently, causing low dissolved oxygen releases. The residence time in Lake Powell is also shorter for the low dissolved oxygen plumes under low lake elevations, extending the duration of low dissolved oxygen water being released from Glen Canyon Dam.

Dissolved oxygen levels below Glen Canyon Dam vary throughout the year, falling as low as 2.2 mg/L in the summer and rising as high as 9 to 10 mg/L in the spring (GCMRC 2025). This seasonal variation is due to changes in dissolved oxygen at the penstock level of Lake Powell during the year. The Colorado River dissolved oxygen increases approximately 1 mg/L between Glen Canyon Dam and Lees Ferry. This approximation can vary between negligible re-oxygenation and approximately 3 mg/L increases during very low oxygen releases during daylight hours (GCMRC 2025). Low dissolved oxygen conditions improve downstream of the Paria Riffle and Badger Rapids as the water is reaerated through whitewater action.

In Lake Mead, dissolved oxygen levels decrease in the bottom of Las Vegas Bay as a result of high decomposition of organic matter from the Las Vegas Wash. When there are greater nutrients and algae in surface water, generally more decomposition and low oxygen occur in bottom waters, assuming a stratified system. Monitoring is ongoing to determine the cause of decreased dissolved oxygen concentrations in isolated areas, but the driver is likely higher temperatures from inflows. Backwaters in embayments have little water exchange and tend to be shallower and warmer. These conditions increase the likelihood of algal blooms and issues with low dissolved oxygen conditions,

[4] Tailwater refers to waters located immediately below the dam. It is the reach of river immediately downstream of a reservoir that is heavily influenced by reservoir characteristics. Tailwaters are generally expected have water quality more similar to the reservoir compared to reaches further downstream.

or hypoxia[5] (Reclamation 2016). See **TA 10**, Terrestrial Wildlife Including Special Status Species, for information about algal blooms' effects on wildlife.

TA 6.1.5 Metals

The planning area contains sources of various metals, including selenium and mercury. Selenium and mercury are toxic to fish and wildlife and can accumulate in the food web (Walters et al. 2015).

Soluble hexavalent chromium has been detected in groundwater in two known locations in the Lower Basin: at the former McCulloch Manufacturing Plant in Lake Havasu City, Arizona, and at the Pacific Gas and Electric Compressor Station near Needles, California. Mitigation efforts and plume monitoring are ongoing. The latest groundwater monitoring data indicate that plume migration is not occurring (California Water Boards 2022). The landowner continues to monitor the chromium associated with the former McCulloch Manufacturing Plant at Lake Havasu and Holly Avenues. Based on the latest site investigations, the groundwater chromium plume extended approximately 3,000 feet long and about 600 feet wide from the former McCulloch facility. This remained within the vicinity of the former McCulloch facility, which is several thousand feet from the Colorado River (AZDEQ 2022). Pacific Gas and Electric Company removed soils from 15 locations on federal land and where contaminants could migrate to federal land from the Pacific Gas and Electric Compressor Station and continues to remediate groundwater (AZDEQ 2024).

Within the Basin, about three million gallons of water and sediment at the Gold King Mine near Silverton, Colorado were released into Cement Creek, a tributary of the Animas River (USGS 2018a). In addition to regular monitoring, additional U.S. Geological Survey (USGS) and EPA samples were taken to assess the quality of water quality data, and found detectable levels of heavy metals, such as antimony, arsenic, cadmium, and cobalt, in sediment and surface water samples (EPA 2017).

While there is a historical issue with heavy metals, these point sources are not a typical concern. Therefore, this was not considered further in the analysis.

TA 6.1.6 Perchlorate

Perchlorate is a chemical compound that targets the thyroid under acute exposure (that is, exposure under 14 days or less) and intermediate exposure (that is, exposure that is 15 to 364 days), particularly for iodide deficient individuals and during pregnancy (Agency for Toxic Substances and Disease Registry 2008). Within the planning area, perchlorate contamination was linked to a groundwater plume from the Kerr McGee Chemical Company in Henderson, Nevada. Since 2002, mitigation programs have successfully reduced perchlorate concentrations below applicable regulatory limits throughout the Lower Basin (Hannoun and Tietjen 2022, also cite EPA-815-F-20-002). Although a low-level, continuous release from the source area remains a concern, ongoing long-term monitoring programs enable adaptive management and ensure perchlorate is effectively managed under future operational scenarios.

[5] Low levels of dissolved oxygen that can have detrimental effects on the ecological and economic health of affected areas.

TA 6.1.7 PFAS

Adjacent to Lake Mead, PFAS was detected in the Las Vegas Wash. PFAS in the Las Vegas Wash likely entered via municipal wastewater effluents, of which the likely main source was residential wastewater. PFAS concentrations were relatively low for the small tributary associated with a smaller urban airport, so that airport is an unlikely significant PFAS source (Thompson n.d.). Generally, as reservoir elevations decrease, the dilution capacity of reservoirs like Lake Powell and Lake Mead would also decrease. Decreased dilution capacity from lower reservoir elevations could result in greater concentrations of pollutants of concern, such as PFAS.

TA 6.2 Environmental Consequences

TA 6.2.1 Methodology

The analysis methodology for water quality is based on a combination of Decision Making under Deep Uncertainty (DMDU); Colorado River Simulation System (CRSS); Grand Canyon Monitoring and Research Center Dissolved Oxygen & Temperature Models for Glen Canyon, Lees Ferry, and Grand Canyon; and qualitative analysis.

The CRSS model simulates Basin conditions decades into the future and can account for hydrological uncertainty. The CRSS model is a monthly time step model that produces reservoir elevations, dam releases, and salinity concentrations. The CRSS model does not consider potential decreases in calcium carbonate precipitation (that is, the mechanism by which Lake Powell reduces the downstream transport of salt on annual to decadal time scales) that might occur at lower reservoir elevations when residence time is lower. Using an equation developed by the USGS (USGS 2018b), which can be classified as a hybrid between a mechanistic and statistical model, salinity at Imperial Dam is calculated as a function of Hoover Dam salinity, Parker Dam releases, and diversions by Colorado River Indian Reservation and Palo Verde Irrigation District. Refer to **Appendix A**, CRSS Model Documentation, for more details on model documentation.

In this section, salinity is analyzed as it relates to the salinity criteria set by the Colorado River Salinity Control Forum. For information on salinity concentration and salinity related to the potential effects on resources in the International Border Region, see **Appendix N**, International Border Region of the Colorado River.

Impacts on water quality are described using conditional box plots and vulnerability bar plots based on CRSS model outputs, and Grand Canyon Monitoring and Research Center models. Refer to **Section 3.2**, Analysis Methods, for additional information on DMDU and **Appendix E**, DMDU Overview and Approach, for an overview of how interpret the DMDU conditional box plots, robustness heat maps, and vulnerability bar plots.

Decision Making Under Deep Uncertainty Modeling

To assess future alternatives and management strategies, a modeling analysis known as DMDU was applied to systematically evaluate potential system responses across a wide range of plausible futures. The analysis incorporated five alternative scenarios, which are the No Action, Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (Lower Basin

Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) Alternatives, representing various flow conditions and the continuation of the current flow management strategies from Lake Powell (Continued Current Strategies [CCS] Comparative Baseline). These alternative scenarios are designed to span a broad spectrum of uncertainty, allowing examination of impacts on resources under several alternatives and baseline conditions. By comparing outcomes across these alternative futures, DMDU quantifies water quality impacts compared to historic conditions, with data interpretation (for example, reservoir elevation and flow conditions by alternative). If an alternative achieves a robustness score of 90 percent or higher, it can be considered truly robust with respect to a particular resource. When the difference in robustness between alternatives exceeds 10 percent, one alternative can be considered more robust than another. If the difference is less than 10 percent, the alternatives are considered similarly robust. Models were considered based on a multiagency cooperation of resource impacts.

DMDU figures are presented to provide comprehensive and reliable information about potential system outcomes under each alternative, regardless of future uncertainties. By intentionally disconnecting the analysis from probabilistic interpretation, these figures focus attention on key resource concerns and improve our understanding of how each alternative performs across a range of hydrologic conditions and are presented to provide comprehensive and reliable information about potential system outcomes under each alternative, regardless of future uncertainties.

Robustness Heat Maps

Robustness heat maps evaluate how each alternative performs across a wide range of future scenarios over extended modeling periods, such as decades or the entire simulation horizon (2027–2060). Unlike conditional boxplots, which assess each year independently, heat maps aggregate results according to resource-specific definitions of "acceptability," using thresholds and frequencies to classify scenarios as successful or not. Each alternative is assigned a robustness score, indicating the percentage of futures where performance criteria are met, with higher scores reflecting greater robustness. The heat maps display multiple levels of performance, from the most challenging criteria at the top to the least stringent at the bottom, and use a highlighted row to emphasize key acceptability thresholds or significant comparison points. This color-coded format distills complex modeling results into an accessible, comparative framework, enabling readers to quickly compare alternatives, understand their relative robustness, and make informed decisions.

Vulnerability Bar Plots

Vulnerability bar plots display, for each alternative, the hydrologic conditions, based on a key Lees Ferry natural flow statistic, under which threshold outcomes are classified as preferred minimum performance (blue) or undesirable performance (red), such as during the worst 10-year drought. This visual division highlights the specific scenarios that lead to vulnerability, with larger blue regions indicating greater robustness. Accompanying boxplots provide context by relating these vulnerability thresholds to recent observations and a wide range of plausible future scenarios. The primary purpose of the vulnerability bar plot is to clarify the conditions under which an alternative is likely to fail and to determine whether those conditions fall within the range of what can reasonably be anticipated, thus informing decision-makers about each alternative's limits and resilience.

Grand Canyon Monitoring and Research Center Dissolved Oxygen and Temperature Models for Glen Canyon, Lees Ferry, and Grand Canyon

Dissolved Oxygen Model

Generalized linear mixed models were constructed to predict metalimnion dissolved oxygen content at the reservoir forebay (site name "Wahweap" LPCR0024). 176 water quality profiles were used from July, August, September, and October 1967–2023 to calculate the mean metalimnion dissolved oxygen concentration. Profiles were generally collected monthly at Wahweap, although some data gaps exist. Prior to 2010, water quality profiles were conducted by manually taking a reading every time one of the water quality parameters changed by a predetermined amount. After October 2010, a 4-Hertz profiler was used to collect measurements in continuous mode and bin data into 0.5-meter increments. The metalimnion depth in Lake Powell can vary widely, with deeper and more diffused metalimnions in years with large spring inflows. Dissolved oxygen concentrations were averaged between 7- and 50-meter, taking a broad definition of the metalimnion to encompass the order of magnitude differences observed in spring inflow volume (Deemer et al. 2025; Deemer et al. 2026).

Generalized linear mixed models were built to predict dissolved oxygen concentrations as a function of day of year, minimum reservoir elevation in that year, volume of spring inflow (calculated as total inflow from April to July), reservoir age (calculated in years since 1963), and 3 interaction terms: age by elevation, spring inflow by elevation, and age by spring inflow interaction with year as a random effect. Metalimnion water temperatures were positively correlated with the volume of the spring inflow (Pearson correlation = 0.61), so water temperature was not included in modeling efforts, given its weaker relationship to mean metalimnion dissolved oxygen concentration. At a yearly scale, the Pearson correlation between inflow and mean dissolved oxygen was −0.26, whereas the Pearson correlation between water temperature and mean dissolved oxygen was −0.19. Before modeling, all noninteractive predictors were standardized by subtracting the mean predictor value and dividing by the standard deviation of the predictor value. Interactions were then calculated as the product of the standardized predictors. Day of year was represented as the calendar day (183–304) standardized. The standardized calendar day was then squared for a second predictor term. Modeling was done in R 4.3.0 (R Core Team 2020) using the lmer function, and best models were selected based on Akaike information criterion values and a priori 2-stage buildup model selection strategy. All main effects were considered in the first stage, and any models within 5 Akaike information criterion of the best model were carried forward, and in the second stage all potential 2-way interactions among main effects selected in the first stage were considered as additions to the models identified in the first stage (Deemer et al. 2025; Deemer et al. 2026).

To test for monsoonal influence on reservoir dissolved oxygen concentrations, a proxy for local monsoon activity was developed using daily discharge data from July, August, and September from the Paria River near Kanab, Utah (gage 09381800); the Escalante River near Escalante, Utah (gage 09337500); Chinle Creek near Mexican Water, Arizona (gage 09379200); the San Rafael River near the Green River, Utah (gage 09328500); and the Dirty Devil River Above Poison Springs Wash near Hanksville, Utah (gage 09333500) from 1980 to 2023. The 43-year average monsoon (July to September) flow at these sites varied from 0.23 cubic meters per second at the Escalante to 2.59 cubic meters per second at the San Rafael. Flows were normalized from all gages to the average flow across all gages (1.39 cubic meters per second) by multiplying each daily discharge measurement by 1.39 and dividing by the site-specific long-term average. The mean normalized daily flow was then

calculated during July, August, and September across the 5 gages. The described generalized linear mixed modeling model selection strategy was repeated with this added monsoonal predictor using the subset of the data from 1980 forward (Deemer et al. 2025; Deemer et al. 2026).

Following the same procedure as for the reservoir forebay, generalized linear mixed models were constructed to predict metalimnion dissolved oxygen concentration at six additional sites within Lake Powell with at least 40 separate years of available profile data from at least 1 month spanning July to October. Five of the six sites were on the Colorado River arm, and one site was on the San Juan River arm of Lake Powell (Deemer et al. 2025; Deemer et al. 2026).

To support predictive modeling of dissolved oxygen in dam releases, six depth-specific models of monthly metalimnion dissolved in the reservoir forebay were constructed using the same model selection approach described earlier. Models were set up to predict dissolved oxygen in 10-meter depth bins starting 6 meters below the reservoir surface and extending down to 66-meters. Instead of predicting mean dissolved oxygen across the period, the models were set to predict the minimum monthly means, given concern over the minimum dissolved oxygen levels that may be released through the dam to the tailwater. The models can then be combined with reservoir elevation information and the associated depth of the penstock water release structures to predict the likelihood that dissolved oxygen concentrations will drop below threshold values each season. The probability of falling below a particular threshold was then determined from the cumulative probability distribution described by a predicted minimum and the estimated standard deviation associated with a model (that is, ignoring parameter uncertainty, a relatively small source of error; Deemer et al. 2025; Deemer et al. 2026).

Water Temperature Model

The Dibble et al. 2020 water temperature model, an equilibrium temperature model with empirically estimated parameters, was developed by fitting relationships to monthly average water temperature data collected from 1985 to 2015 at 44 gages along the Colorado, Gunnison, Green, Yampa, Duchesne, White, San Juan, and Animas rivers. Solar radiation and air temperature represent the primary components in the simplified heat budget that determines river temperature. The model also accounted for major tributaries (that is, mean annual flow greater than or equal to 10 percent of the mainstem river). To estimate model suitability, the model was first fit to data from odd years. Data from even years were used to calculate the root mean square error and overall bias of out-of-sample prediction aggregated by river segment and month of year. Then, the model was fit using all data, producing estimates with similar means but higher precision. The estimates were used to predict water temperatures for the current period (1985 to 2015) at a 1-river-kilometer resolution along 2,560 river-kilometer of river (Dibble 2020).

Future water temperature scenarios were determined by using air temperature predictions from phases 3 and 5 of the Coupled Model Intercomparison Project models to understand how air temperatures may change by mid-century (2040 to 2059) relative to 1950 to 1999. On average, air temperatures in the Basin are predicted to increase by 1.85 to 3.01 °C (35.3 to 37.4 °F) per month by mid-century, averaging approximately 2.6 °C (36.7 °F) on an annual basis. An annual air temperature increase of approximately 2.6 °C (36.7 °F) would reduce mean annual flow in the Basin by approximately 17 percent through greater evaporation, evapotranspiration, and sublimation, among others. Inputs into the model

considering climate only used predicted increases in monthly air temperature, combined with predicted declines in Colorado River flow. Inputs into the storage plus climate scenario used nonlinear regression (least squares) to predict reservoir release temperatures as a function of storage elevation by month, which permitted an assessment of the degree to which changes in reservoir storage affect riverine thermal regimes relative to warming alone. This analysis included data spanning 1965 to 2015 from five large storage reservoirs in the Basin (Fontenelle, Flaming Gorge, Navajo, Glen Canyon, and Hoover). The predicted water temperature associated with the lowest recorded storage elevation for each reservoir was used to predict potential warming of releases if storage was deemphasized. As such, the low storage adjustment represents predicted river temperature at the lowest storage after reservoirs initially filled relative to the base model (Dibble 2020).

The Eppeheimer et al., 2025 water temperature model includes the segment of the Colorado River flowing through Glen, Marble, and Grand canyons in Arizona that is bounded by Lake Powell and Lake Mead. Water from the upstream Lake Powell is released through Glen Canyon Dam and flows approximately 475 river-kilometers before entering Lake Mead. Riverine environmental conditions and aquatic communities change dramatically over its length. A dam tailwater segment is located in the first 25 river-kilometers downstream of Glen Canyon Dam and is characterized by clear water, abundant aquatic vegetation, and water temperatures almost entirely determined by reservoir release temperatures. Water temperature is measured every 15 minutes near the bottom of this river segment at the Lees Ferry gage (USGS gage: 09380000) near the location of Lee Ferry that demarcates the Upper and Lower Basins. Since 1973, the tailwater segment was characterized by three decades of very cold water temperatures (95 percent range of daily water temperatures: 7.6 to 11.3 °C [45.7 to 52.34 °F] at the Lees Ferry gage), followed by approximately two decades of cool water temperatures prior to 2022 (95 percent range of daily water temperatures: 8.1 to 14.3 °C [46.6 to 57.7 °F] at the Lees Ferry gage) and was managed as a Blue Ribbon rainbow trout fishery. Downstream from the tailwater segment and the Lees Ferry gage, the river becomes more turbid, aquatic vegetation becomes rare, and water temperatures gradually warm in the summer. Approximately 122 river-kilometers downstream from the Glen Canyon Dam, the Colorado River reaches its confluence with the Little Colorado River, a tributary that was once the only spawning site for humpback chub, and is currently a population center for humpback chub in Grand Canyon. Further downriver, the humpback chub population has increased dramatically over the last decade in a river segment approximately 200 river-kilometers in length. This river segment is frequently referred to as the western Grand Canyon and is approximately centered on the confluence of the Colorado River with Diamond Creek (approximately 386 river-kilometers downstream from Glen Canyon Dam). The two models separately estimate small-mouth bass propagule pressure from Lake Powell to the tail-water segment and the potential for smallmouth bass population growth based on Colorado River temperatures at the Lees Ferry gage, the Little Colorado River confluence, and the Diamond Creek confluence (Eppeheimer et al. 2025).

The model estimated smallmouth bass propagule pressure from Lake Powell by modeling rates of fish passage through Glen Canyon Dam which were assumed to be a function of (1) Lake Powell elevation, (2) predicted river temperatures by fitting and forecasting from a novel model of Glen Canyon Dam release temperatures combined with a previously published model of river warming below Glen Canyon Dam, and (3) estimated the probability of smallmouth bass asymptotic

population growth exceeding one under various scenarios based on predicted daily average water temperatures and a matrix model (Eppeheimer et al. 2025).

Glen Canyon Dam can release water through penstocks and river outlets. Typically, water is passed through the penstocks at a centerline elevation of 3,470 feet to generate hydropower; turbines likely cause high mortality but do not prevent successful fish passage. Water can also be released through the deeper river outlets (centerline of 3,370 feet). However, the river outlets do not generate hydropower, so their use is rare. Results presented here assume all water is passed through the penstocks until reservoir elevations are at or below 3,490 feet, at which point releases switch to river outlets to avoid damaging hydropower infrastructure. Both the smallmouth bass propagule pressure and smallmouth bass population growth models rely on Lake Powell elevations, which we estimated using a water resource operations model used by Basin managers. In the water resource operations model, changes in Lake Powell elevation are modelled monthly as a function of starting elevation, inflows, outflows, bank storage, and evaporative losses. A range of future conditions was considered using combinations of starting elevations at the beginning of a year, annual inflows, and annual outflows. We considered starting elevations ranging from 3,470 (18 percent of capacity) to 3,600 feet (50 percent of capacity). Inflows were based on resampling the past 23 years (2000–2022). Inflows during this period varied from 4 to 15 million acre-feet (maf) per year. In our analyses, we assumed one of two scenarios for annual outflows: (1) 7.48 maf per year outflows with monthly patterns derived from Reclamation's projections (these are the anticipated outflows for the near-term based on current water management agreements) and (2) a potential management scenario in which reservoir levels are held constant over the course of a year by matching monthly dam release volumes with monthly inflow volumes (this scenario will be referred to as "maintain elevation"). We also produced forecasts for 2025 using the 2025 calendar year projected Lake Powell starting elevation of 3,572 feet, 2025 predicted outflows as of October 2024, and 23 historic inflow traces (2000 to 2022) characterizing inflow variability (Eppeheimer et al. 2025).

Impact Analysis Area

The analysis area for water quality is the geographic and temporal scope introduced in **Section 3.2**. Due to the data available, analysis was limited to surface water quality.

While reduced water deliveries could have impacts on downstream municipal users, the analysis does not include an analysis of these impacts since the operations of municipal water providers fall outside of Reclamation's regulatory authority and are carried out independently by these third parties.

Assumptions

- There will be modifications in quantity, timing, temperature, and quality of water released from Glen Canyon Dam and Hoover Dam.

Impact Indicators

- Salinity
- Temperature
- Dissolved oxygen
- Reservoir elevation
- Dilution capacity

TA 6.2.2 Issue 1: How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect salinity?

Increased salinity concentrations from human activities pose a threat to drinking water, irrigation, agricultural production, municipal water supplies, and infrastructure. Reservoirs like Lake Powell and Lake Mead influence salinity by attenuating salinity transport downstream and possibly acting as a source or a sink (Deemer et al. 2020). Reservoirs also modulate the downstream transport of salinity (Deemer et al. 2020) by reducing the baseflow peaks in salinity and increasing the snowmelt troughs (Deemer et al. 2020; Moody and Mueller 1984). On an annual timescale or longer, reservoirs have been found to reduce salinity (for example, a 10 percent reduction in downstream TDS for Lake Powell, Deemer et al. 2020), although the extent to which this effect applies to other Basin reservoirs is unknown. Dam releases are typically from deeper in the water column and generally have elevated salinity concentrations relative to surface waters. As reservoir water levels drop, reservoir salinity can often increase (Zohary and Ostrovsky 2011).

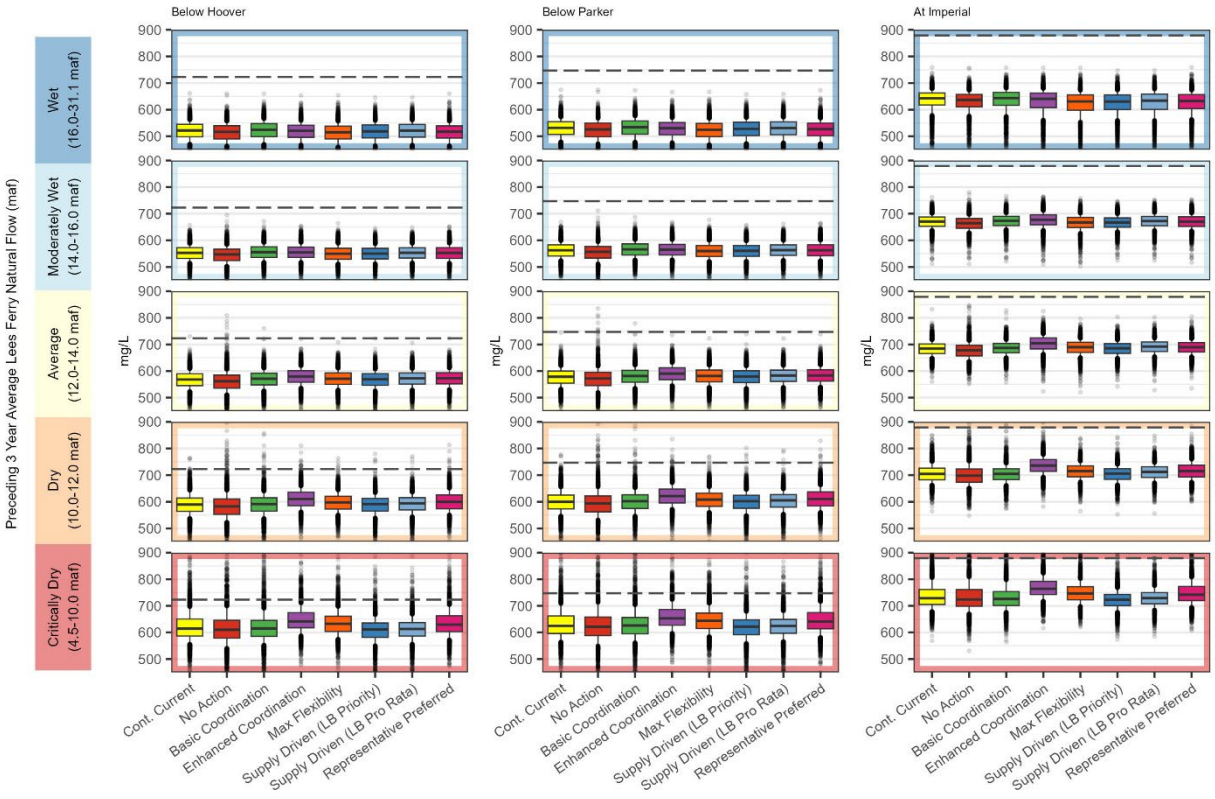
Figure TA 6-4 shows simulated salinity concentrations below Hoover Dam, below Parker Dam, and at Imperial Dam for each alternative using conditional boxplots. The box plots show how the alternatives perform under varying hydrologic conditions, defined by the preceding three-year average of Lees Ferry natural flow. The bottom and top of each box captures the 25th to 75th percentile of the modeled results, respectively. The lines extend to the 10th and 90th percentiles, and outliers are shown as dots. For comparison against the Colorado River Basin Salinity Control Forum's salinity water quality standards, the figure displays critical thresholds as a dashed line representing the salinity thresholds below Hoover Dam, below Parker Dam, and at Imperial Dam[6] (that is, 723 mg/L, 747 mg/L, and 879 mg/L, respectively).

Figure TA 6-4 also shows that below Hoover Dam, under the Average Flow Category only the No Action and Basic Coordination Alternatives exceed the critical salinity threshold, but a majority (90 percent or greater) of simulated futures does not exceed the critical salinity criteria. The highest median salinity concentrations occur in the Enhanced Coordination Alternative, with the greatest difference between alternatives in the Critically Dry Flow Category. Under the Dry Flow Category, all alternatives exceed the critical salinity threshold, but like under the Average Flow Category modeled conditions, a majority (90 percent or greater) of simulated futures does not exceed the salinity criteria. Further, under the Critically Dry Flow Category, more futures exceed the threshold, yet the majority of futures still remain below the critical salinity threshold. Overall, under all alternatives, the interquartile range (the middle half of the outputs, including the median) is narrow and does not exceed the salinity criteria under any of the hydrologic conditions. Therefore, a majority (90 percent or greater) of simulated futures do not exceed the salinity criteria in even the most challenging hydrologic conditions. The dynamics below Parker Dam and at Imperial Dam are similar to that below Hoover Dam where, under all alternatives and all locations, the distributions of annual flow-weight average salinity increases as conditions get drier but of which a majority of

[6] The Colorado River Basin Salinity Control Forum does not have a water quality standard for Glen Canyon Dam; therefore, Glen Canyon Dam was not included in this analysis.

simulated futures does not exceed the critical salinity threshold. See **Table TA 6-2** at the end of this technical appendix for the upper extremes of the outputs shown in **Figure TA 6-4**.

Figure TA 6-4
Annual Flow-Weighted Average Salinity Concentrations



Note: Supply Driven Alternative (LB Priority approach) and Supply Driven Alternative (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Under the Dry Flow Category, the Representative Preferred Alternative exhibits a median of 600 mg/L and a narrow interquartile range for salinity. Under the Critically Dry Flow Category, the Representative Preferred Alternative exhibits a median of 630 mg/L and a narrow interquartile range. These results are within the range analyzed across the other alternatives from the Draft EIS. The Representative Preferred Alternative falls below the critical salinity threshold under a majority of futures in the Critically Dry Flow Category.

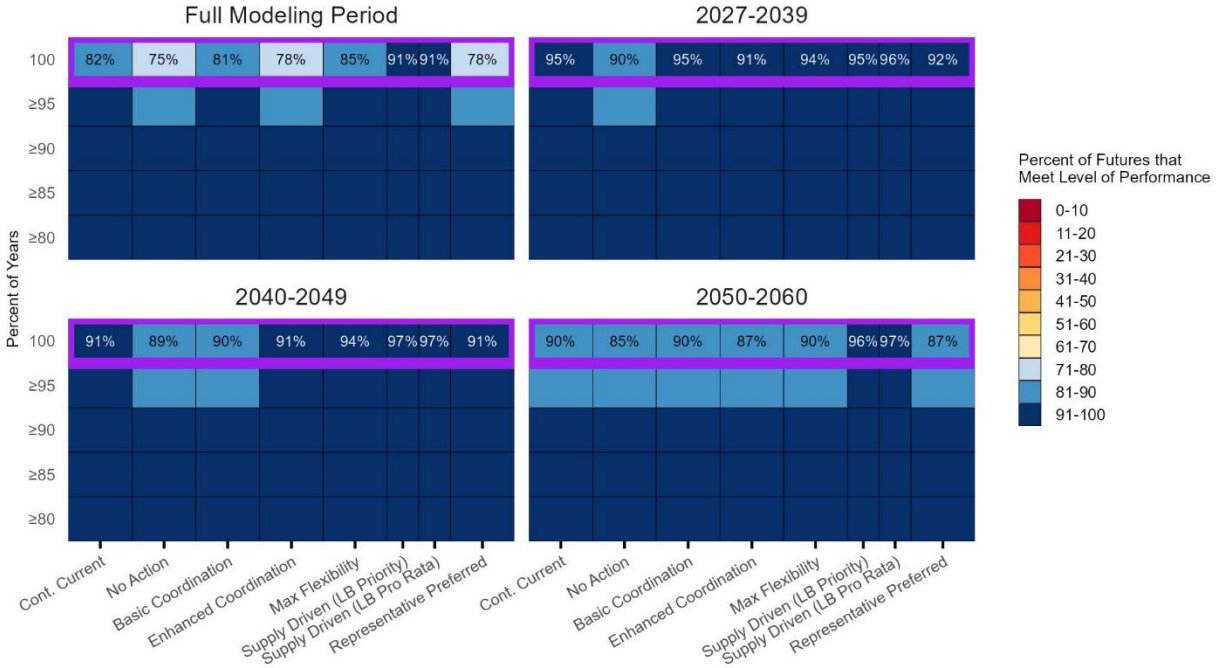
In **Figure TA 6-5**, **Figure TA 6-6**, and **Figure TA 6-7**, the percent of futures in which the salinity concentration is less than 723 mg/L, 747 mg/L and 879 mg/L, respectively, are used to assess performance with respect to meeting the salinity criteria of the Colorado River Basin Salinity Control Forum. The highlighted rows in **Figure TA 6-5**, **Figure TA 6-6**, and **Figure TA 6-7**

compare alternatives with respect to the salinity concentration in 100 percent of years to compare adherence to the salinity criteria. Lower rows represent lower percentages that are easier to achieve.

Over the first decadal period (that is, 2027 to 2039), **Figure TA 6-5** shows that all alternatives are truly robust, meeting the preferred level of performance in 90 percent of futures or greater. In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. The Representative Preferred Alternative is less than 723 mg/L over 100 percent of years in 92 percent of modeled futures in the first decade.

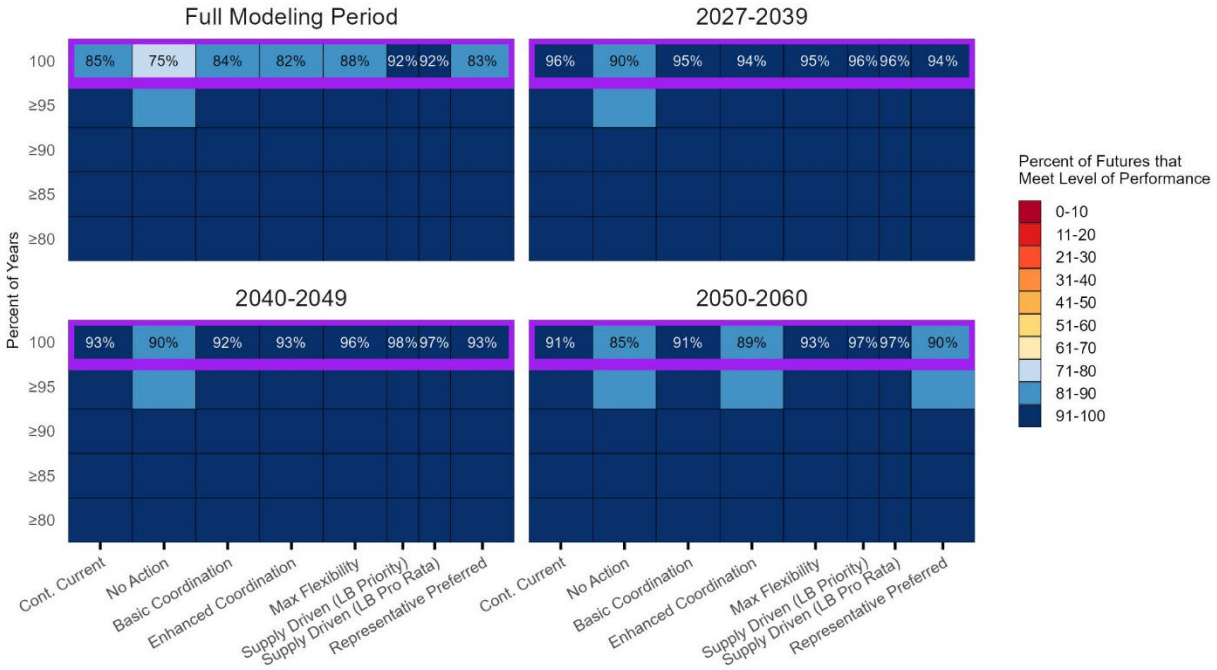
It can be inferred that the annual flow-weighted salinity concentrations below Parker Dam and at Imperial Dam are correlated with those below Hoover Dam, as the median salinity values and interquartile ranges consistently increase as hydrologic conditions get drier and follow a similar pattern across all alternatives in **Figure TA 6-4**.

Figure TA 6-5
Salinity Below Hoover: Robustness.
Percent of futures in which the salinity concentration is less than 723 mg/L in the percent of years specified in each row



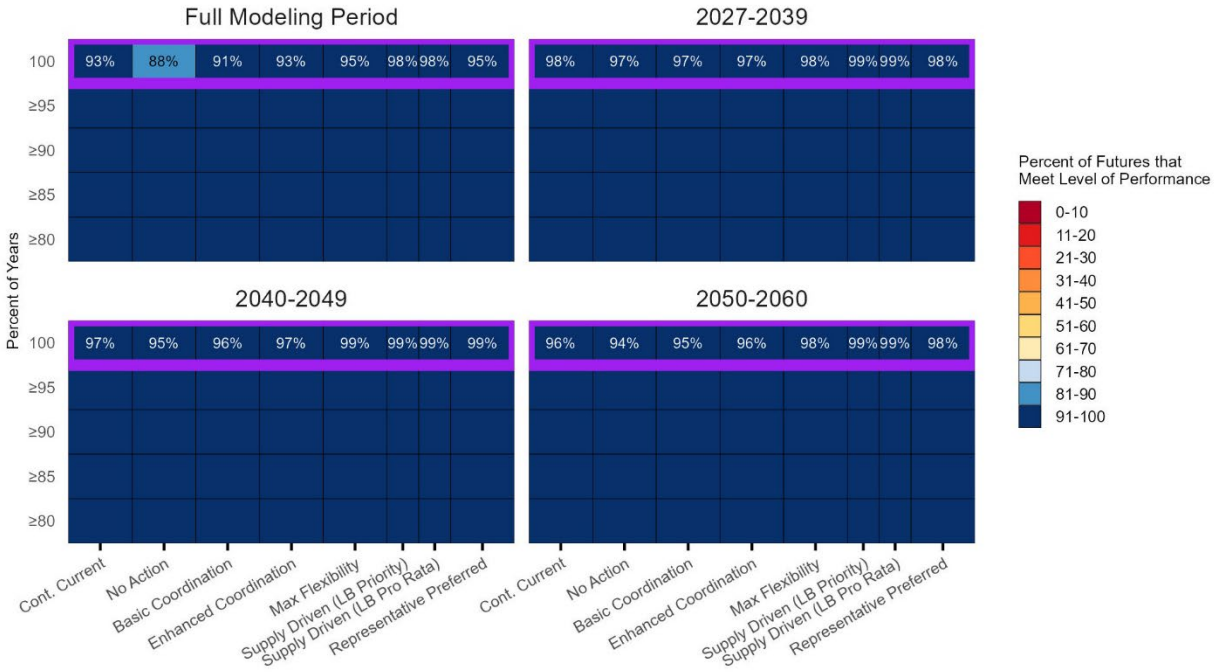
Note: Supply Driven Alternative (LB Priority approach) and Supply Driven Alternative (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Figure TA 6-6
Salinity Below Parker: Robustness.
Percent of futures in which the salinity concentration is less than 747 mg/L in the percent of years specified in each row



Note: Supply Driven Alternative (LB Priority approach) and Supply Driven Alternative (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

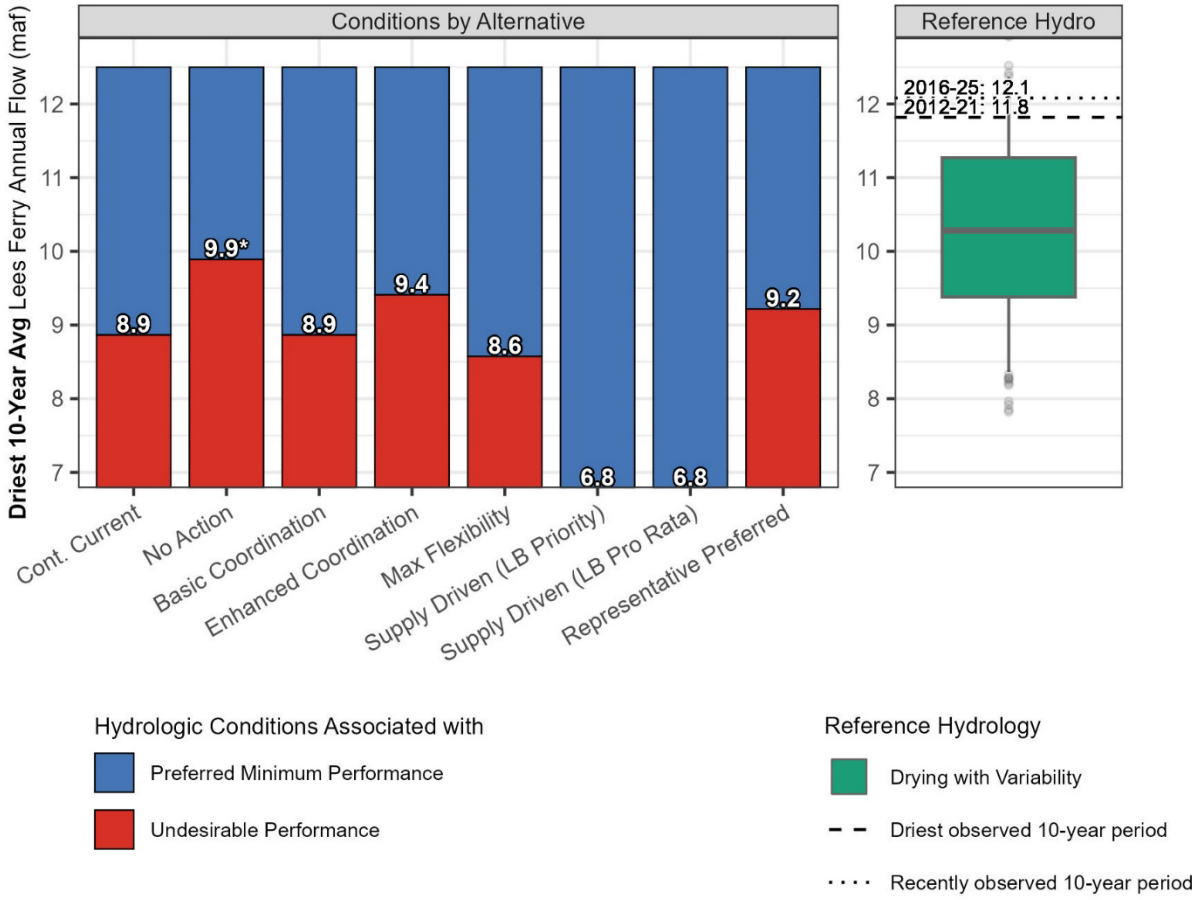
Figure TA 6-7
Salinity at Imperial: Robustness.
Percent of futures in which the salinity concentration is less than 879 mg/L in the percent of years specified in each row



Note: Supply Driven Alternative (LB Priority approach) and Supply Driven Alternative (LB Pro Rata approach) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Since the salinity below Parker Dam and at Imperial Dam correlates closely with the simulated salinity concentrations below Hoover Dam, a vulnerability analysis was completed for salinity below Hoover Dam to represent all three sites. **Figure TA 6-8** highlights the preferred minimum performance level of salinity below Hoover Dam above 723 mg/L in one or more years to capture the conditions that would cause a failure to meet the salinity criteria. To identify hydrologic conditions that could cause undesirable performance, the incidence of annual flow-weighted average salinity concentration below Hoover Dam in at least 1 year over the 34-year modeling period was analyzed. The distribution of driest 10-year average volumes in the reference hydrology was identified as a good predictor of undesirable performance. The reference hydrologic panel shows the range of driest 10-year average flows represented in a reference hydrology along with the most recent and driest observed 10-year periods. The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 9.2 maf or less. Compared to the historical periods shown in the reference hydrologic panel, this flow has occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, less than 25 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Figure TA 6-8
Salinity at Hoover: Vulnerability.
Conditions that Could Cause Salinity Below Hoover Above 723 mg/L in 1 or More Years.



Note: Results of vulnerability analyses are based on dividing data into two categories and identifying hydrologic conditions that skillfully predict which category a future belongs in. The primary calculation is based on ensuring a high level of skill in predicting futures that meet preferred minimum performance (blue portion) and then confirming that the predictions of futures belonging in the undesirable performance category (red portion) are also skillful. The No Action Alternative has lower skill in predicting the undesirable performance category due to frequent and large dead pool-related delivery reductions, which result in a weaker relationship between natural flow at Lees Ferry and flow weighted salinity concentrations below Hoover. There is the same level of confidence for all alternatives in predicting when they will meet preferred minimum performance.

If the future includes a 10-year average flow of 11.8 maf or lower, modeling results do not indicate undesirable performance for all alternatives; over 75 percent of the reference hydrology include averages this low or lower. Further, the hydrologic conditions associated with undesirable performance for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) (a 10-year drought averaging 6.8 maf or lower), are drier than any conditions in the observed record or the reference hydrologic ensemble, in which the lowest 10-year drought averaged 7.8 maf, so these alternatives have low vulnerability. The CCS Comparative Baseline, and the No Action, Basic

Coordination, Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives are vulnerable to undesirable performance for simulated salinity under a relatively wide range of conditions compared to the least vulnerable alternatives. However, for all alternatives, except the No Action Alternative, more than 75 percent of the traces in the reference hydrology are wetter than these values, so the vulnerability is low. Therefore, no significant negative impacts on salinity were associated with any of the alternatives.

Analysis key takeaways:

- Under the Average Flow Category, the maximum simulated annual flow-weighted salinity concentrations under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives exceed the salinity threshold below Hoover Dam in less than 10 percent of simulated futures.
- Simulated annual flow-weighted salinity concentrations are greatest under the Critically Dry Flow Category under all alternatives due to the lowest reservoir elevations associated with these hydrologic conditions. Under the Critically Dry Flow Category, simulated average flow-weighted average salinity concentration upper extremes exceed the salinity thresholds at all sites under all alternatives. Under all alternatives, a majority (90 percent or greater) of simulated futures do not exceed the salinity criteria in even the most challenging hydrologic conditions.
- Considering the robustness of simulated salinity results, compared with the other alternatives, simulated futures under the No Action Alternative exceed the salinity threshold below Hoover Dam under the greatest percentage of futures over the full modeling period. However, under all alternatives, a majority of simulated futures do not exceed the salinity criteria established by the Colorado River Basin Salinity Control Forum below Hoover Dam, below Parker Dam, or at Imperial Dam.
- Salinity for releases below Parker Dam and at Imperial Dam are highly correlated with releases below Hoover Dam.
- In a vulnerability analysis of conditions that could cause salinity concentrations below Hoover Dam to exceed 723 mg/L in one or more years, the hydrologic conditions associated with undesirable performance are drier than the median reference hydrologic conditions (that is, a 10-year drought averaging 10.3 maf or lower). Further, the hydrologic conditions associated with undesirable performance for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches [a 10-year drought averaging 6.8 maf or lower]) are drier than any conditions in the observed record or reference hydrologic ensemble so these alternatives have low vulnerability. The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 9.2 maf or less. Compared to the historical periods shown in the reference hydrologic panel, this flow has occurred before.

TA 6.2.3 Issue 2: How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect water temperature?

Water temperature strongly influences biological and chemical processes. For example, the temperature of dam releases affects fish population dynamics in downstream river segments, and elevated reservoir temperatures can lead to harmful algal blooms.

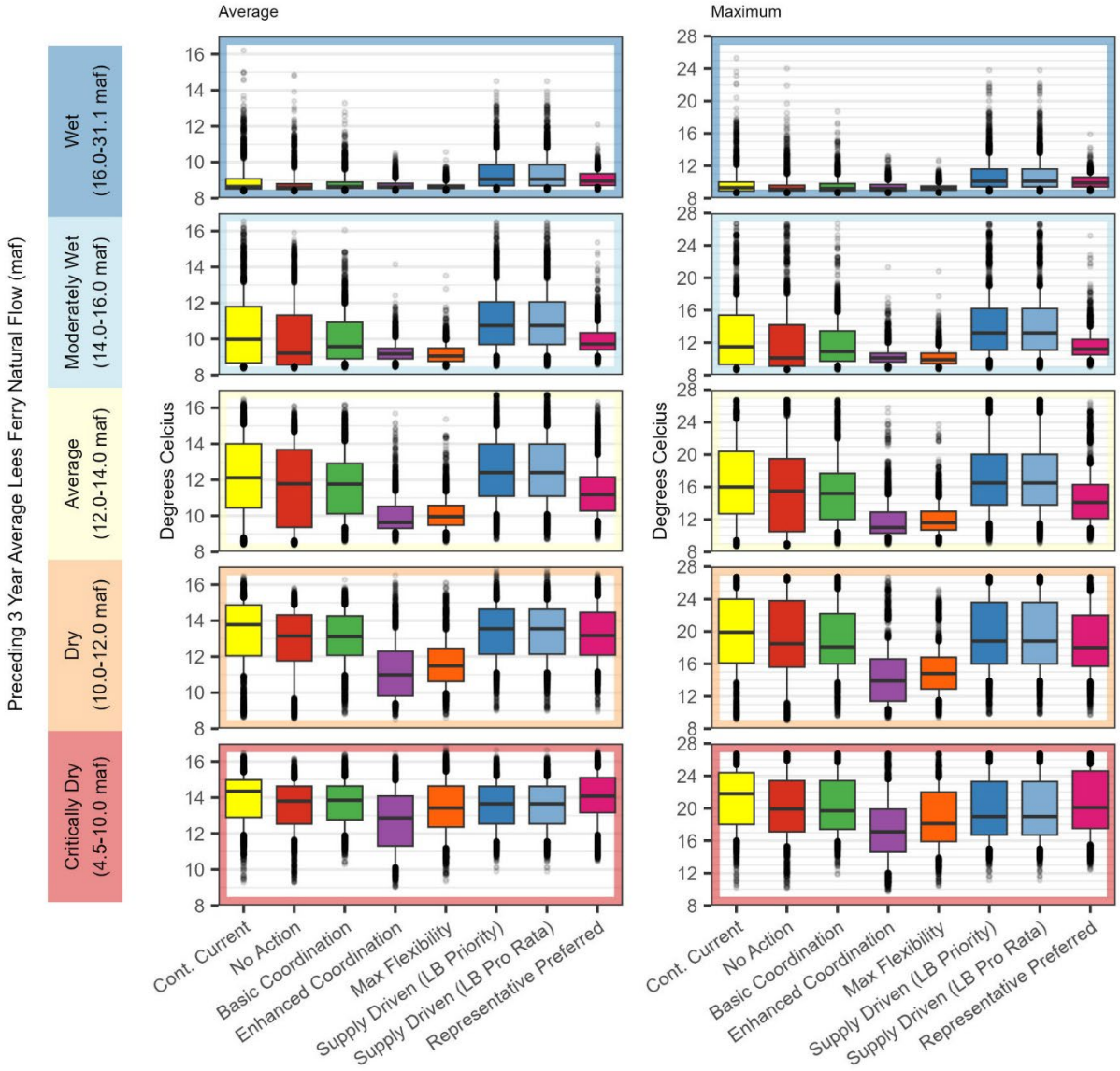
Sections **TA 8.2.3** and **TA 8.2.5**, in **TA 8**, Biological Resources – Fish and Other Aquatic Species, describe the impacts of temperature on fish and other aquatic species at temperature thresholds of 12 °C, 16 °C, and 20 °C (53.6 °F, 60.8 °F, and 68 °F). Exceeding 12 °C (53.6 °F) creates thermal conditions that support mainstream humpback chub growth, which is a desirable response, but exceeding 16 °C (60.8 °F) improves smallmouth bass reproduction at Lees Ferry, which is an undesirable response). For trout species, exceeding the 20 °C (68 °F) threshold reduces rainbow trout survival (exceeding is an undesirable response). According to the life histories of rainbow trout and native Grand Canyon fishes, temperatures above 20 °C (68 °F) are likely to decrease rainbow trout survival while creating conditions more favorable for the growth of native fish and smallmouth bass. Additionally, warmer water temperatures may increase the competitive advantage for brown trout, as this species is more tolerant of elevated temperatures.

Figure TA 6-9 shows simulated Colorado River temperature at Lees Ferry under different hydrologic conditions by looking at the preceding 3-year average of Lees Ferry natural flows. In the Average Flow Category, the median and interquartile ranges for simulated annual average of daily temperatures fall below 12 °C (53.6 °F) for the Enhanced Coordination and Maximum Operational Flexibility Alternatives. Under the Representative Preferred Alternative, the 75th percentile is 12.2 °C (54 °F) with a relatively narrow interquartile range. Under all other alternatives, the interquartile range is large, and exceeds 12 °C (53.6 °F); furthermore, under the CCS Comparative Baseline and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), the 50th percentile exceeds 12 °C (53.6 °F).

Under the driest hydrologic conditions (Dry Flow Category and Critically Dry Flow Category) at Lees Ferry, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have the lowest median values for the annual average of daily temperatures and the annual maximum temperature. The Enhanced Coordination Alternative also has the largest interquartile range under the Critically Dry Flow Category.

Under the Critically Dry Flow Category, under all alternatives, the majority of the average temperatures are greater than 12 °C (53.6 °F). The Enhanced Coordination Alternative has the lowest median and interquartile range. The variability of the maximum values for Colorado River temperature at Lees Ferry is similar to that of the average Colorado River temperature at Lees Ferry. The CCS Comparative Baseline has the highest annual maximum median temperature among all alternatives.

Figure TA 6-9
Average* and Maximum Colorado River Temperature at Lees Ferry**

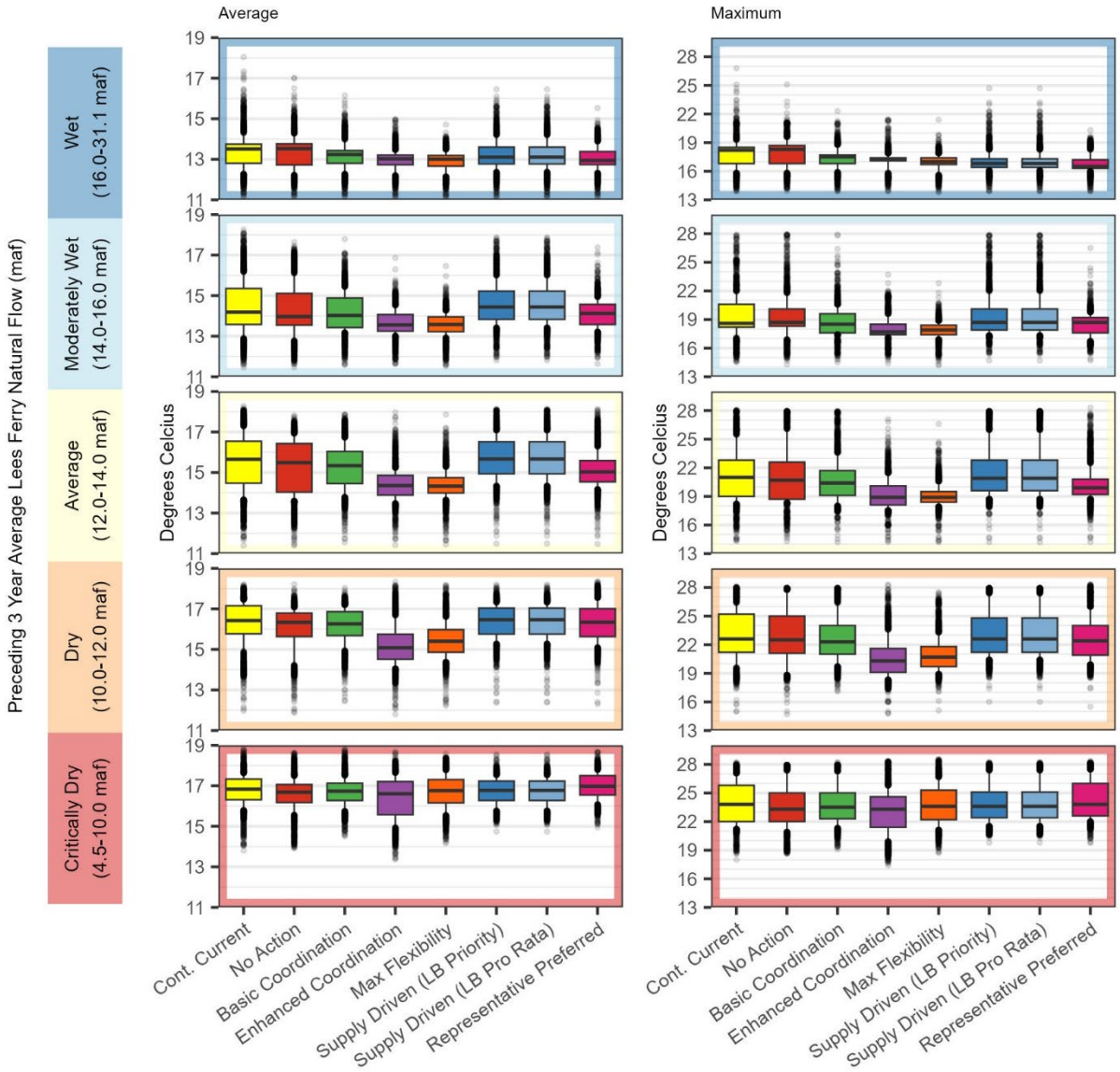


*Average temperature refers to the annual average of daily temperatures.
**Maximum temperature refers to the annual maximum of daily temperature.

Under the Dry Flow Category, the Representative Preferred Alternative exhibits a median annual average of daily temperatures of 13.2 °C (55.8 °F) with a large interquartile range. Further, under the Critically Dry Flow Category, the Representative Preferred Alternative exhibits a median annual average of daily temperatures of 14.1 °C (57.4 °F) with a similarly large interquartile range. These results are within the range analyzed across the other alternatives from the Draft EIS. The 50th percentile of the Preliminary Proposed Preferred Alternative is greater than 12 °C (53.6 °F) in the Critically Dry Flow Category.

As shown in **Figure TA 6-10**, simulated Colorado River temperature at Pearce Ferry trends similarly to Lees Ferry under all alternatives and hydrologic categories. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have the lowest median values for the annual average of daily temperatures and the annual maximum temperature under the Dry Flow Category.

Figure TA 6-10
Average* and Maximum Colorado River Temperature at Pearce Ferry**



*Average temperature refers to the annual average of daily temperatures.
**Maximum temperature refers to the annual maximum of daily temperature.

As shown in **Figure TA 8-9** in **TA 8.2.3**, **TA 8**, Biological Resources – Fish and Other Aquatic Resources, each temperature threshold for fish species was assessed based on the number of days in

which modeled traces exceed the threshold compared to different flow regimes. For drier conditions (that is, the Dry Flow Category and Critically Dry Flow Category), simulated temperatures have higher medians and smaller interquartile ranges than the other hydrologic conditions. Under the driest conditions (that is, the Critically Dry Flow Category), temperatures are expected to exceed 12 °C (53.6 °F) at a higher probability and frequency across all alternatives, with the Enhanced Coordination Alternative having the greatest interquartile range of 124.5 to 220 days.

TA 8.2.3, in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, **Figure TA 8-10** shows the percent of futures in which water temperature does not exceed 20 °C (68 °F), which is the temperature threshold that reduces rainbow trout survival, in one or more days in the modeling period. The 20 °C (68 °F) threshold was analyzed as this is the temperature likely to decrease rainbow trout and native Grand Canyon fishes' survival based on life histories of both fish. The Enhanced Coordination Alternative meets the preferred minimum performance for fish (that is, not exceeding 20 °C [68 °F] in one or more days out of the first decadal period [that is, 2027-2039]) in 62 percent of simulated futures. The Enhanced Coordination Alternative has the greatest number of simulated futures that maintains cooler water temperatures at Lees Ferry, which is beneficial for rainbow trout and limits smallmouth bass reproduction, but these temperatures also inhibit native fish growth and reproduction. Alternatives with larger simulated river flows and higher Lake Powell elevations generally maintain cooler water temperatures in more simulated futures than alternatives with lower simulated river flows and Lake Powell elevations. However, during extended droughts, every alternative has a greater number of simulated futures with undesirable temperature increases, affecting fish habitat and species composition. See **TA 8.2.3** and **TA 8.2.5**, **TA 8**, Biological Resources – Fish and Other Aquatic Species, for more detailed information on changes in water temperature from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry and impacts on sportfish, native Grand Canyon fishes, and nonnative predatory fish.

TA 14.2.2, in **TA 14**, Recreation, describes the impact of temperature on recreation, particularly impacts on sportfish populations. Water temperatures exceeding 20 °C (68 °F) can cause thermal stress and mortality of rainbow trout while creating conditions more favorable for the growth of nonnative fish and smallmouth bass. Additionally, warmer water temperatures may increase the competitive advantage for brown trout, as this species is more tolerant of elevated temperatures. Over the full modeling period, the Enhanced Coordination Alternative has the greatest number of simulated futures that maintain cooler water temperatures at Lees Ferry, which is beneficial for sportfish, like rainbow trout, and limits smallmouth bass reproduction. See **TA 14.2.2**, in **TA 14**, Recreation, for more detailed information on temperature impacts on recreation associated with sportfish populations.

Analysis key takeaways:

- In the Average Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have lower median simulated annual average and maximum daily temperatures, with a narrower interquartile range, compared with other alternatives at both Lees Ferry and Pearce Ferry.
- Under Dry and Critically Dry Flow Categories, the Enhanced Coordination Alternative have the lowest median values for simulated annual average of daily temperatures and maximum

temperatures. Additionally, the interquartile ranges increases across all alternatives, indicating more variability in annual average of daily temperatures and maximum temperatures as flow conditions become drier.

- The Enhanced Coordination Alternative has the greatest number of simulated futures that maintained cooler water temperatures at both Lees Ferry and Pearce Ferry, which is beneficial for rainbow trout and limits smallmouth bass reproduction, but these temperatures also inhibit native fish growth and reproduction.

TA 6.2.4 Issue 3: How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect dissolved oxygen?

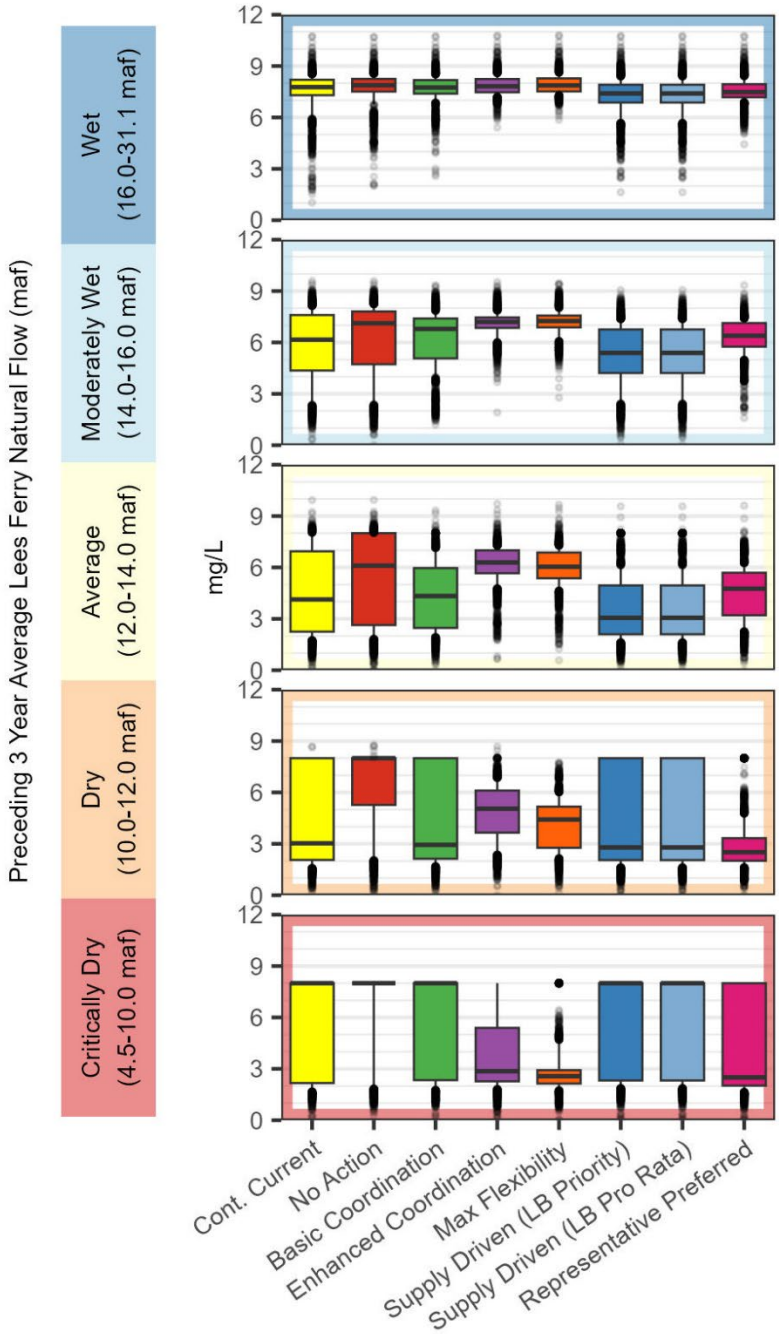
Dissolved oxygen dynamics can be affected by reservoir drawdowns through several pathways, including remobilization of deposited sediment as water levels change. Lower reservoir elevations may result in plumes of low dissolved oxygen from resuspended sediment at the penstock elevation. Thus, the effects of reservoir storage will likely vary based on inflow conditions, with an increased potential for greater variability between annual minimum and maximum concentrations (Deemer et al. 2025). As older reservoirs like Lake Powell experience lower elevations, there is greater metalimnion dissolved oxygen consumption, with larger spring snowmelt inflows furthering dissolved oxygen declines (Deemer et al. 2025). Dissolved oxygen is also affected by certain operations. For example, as reservoir levels decrease below 3,490 feet at Lake Powell, use of the river outlet works is triggered, which leads to high dissolved oxygen concentrations downstream of the Glen Canyon Dam due to aeration as water passes through the river outlet works (Vernieu 2010).

Figure TA 6-11 displays the response of minimum annual dissolved oxygen concentrations released from Glen Canyon Dam to different hydrologic conditions under the alternatives by looking at the preceding 3-year average of Lees Ferry natural flows.

Under the Average Flow Category modeled conditions, the 50th percentile of minimum annual dissolved oxygen concentration released from Glen Canyon Dam is lowest (that is, around 3 to 5 mg/L) for CCS Baseline and the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives; the interquartile range is relatively wide compared with most of the other alternatives. The 50th percentile is highest and the interquartile range is most narrow for the Enhanced Coordination and Maximum Operational Flexibility Alternatives compared with the other alternatives. The 50th percentile is similar to that of the Enhanced Coordination and Maximum Operational Flexibility Alternatives for the No Action Alternative, but the interquartile range is largest.

Analysis of minimum annual dissolved oxygen concentrations under various hydrologic scenarios shows that, in wetter years (that is, the Wet Flow Category), median dissolved oxygen levels are similar across all alternatives, generally falling between 7 and 8 mg/L (see **Figure TA 6-11**).

Figure TA 6-11
Minimum Annual Dissolved Oxygen Concentration Released from Glen Canyon Dam*



*8 mg/L is used as a conservative minimum when Lake Powell's elevation drops below 3,490 feet and dam operations use the river outlet works to pass water through the dam (Deemer et al. 2025). Under the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, and the CCS Comparative Baseline, the median, upper quartile, and maximum values are 8 mg/L in the Critically Dry Flow Category; therefore, the upper quartile is collapsed to a single point that is the same value as the median. Under the No Action Alternative, the maximum, the upper quartile, median, and lower quartile values are 8 mg/L in the Critically Dry Flow Category; therefore, the box is collapsed to a single point and represented as a single horizontal line.

Under the Dry Flow Category modeled conditions, the 50th percentile value of the minimum annual dissolved oxygen concentration released from Glen Canyon Dam decreases under all alternatives and the interquartile range increases for all alternatives except the No Action Alternative. Under the Critically Dry Flow Category modeled conditions, the 50th percentile for the CCS Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives is 8 mg/L, since 8 mg/L is used as a conservative minimum when Lake Powell's elevation drops below 3,490 feet and dam operations use the river outlet works to pass water through Glen Canyon Dam (Deemer et al. 2025). However, given the large lower interquartile ranges, it is difficult to predict how each of these alternatives may respond. Under the Critically Dry Flow Category modeled conditions, the 50th percentile is lower and the interquartile range is narrower for the Enhanced Coordination and Maximum Operational Flexibility Alternatives, since Lake Powell's elevation stays above 3,490 feet in a majority of simulated futures, thus dam operations does not use the river outlet works in a majority of simulated futures (see **Figure TA 3-6** in **TA 3.2.1**, **TA 3**, Hydrologic Resources).

Under the Dry Flow Category, the Representative Preferred Alternative exhibits a median minimum annual dissolved oxygen concentration of 2.5 mg/L and a narrow interquartile range. Under the Critically Dry Flow Category, the Representative Preferred Alternative still exhibits a median of 2.5 mg/L but a large interquartile range for minimum annual dissolved oxygen concentration. These results are within the range analyzed across the other alternatives from the Final EIS.

In **Figure TA 6-12**, the minimum annual dissolved oxygen concentration of Glen Canyon Dam releases in at least 90 percent of years is used to assess performance because it captures the lowest annual dissolved oxygen concentration within a year. The row with the minimum dissolved oxygen concentrations greater than 2 mg/L is highlighted, as this is considered hypoxia in most streams and rivers (Blaszczak et al. 2023). Over the first decadal period (that is, 2027-2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred level of performance in 82 percent and 76 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 29 percent and 48 percent of futures, respectively. The Basic Coordination is similarly robust to the CCS Comparative Baseline, meeting the preferred level of performance in 38 percent of futures. The Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives are similarly robust to the No Action Alternative, meeting the preferred level of performance in 46 percent and 49 percent of futures, respectively. The first decadal period begins with relatively low reservoir elevations, which results in poorer first-decade performance.

When Lake Powell's elevation drops below 3,490 feet, dam operations will use the river outlet works to pass water through the dam. To capture this change to dam operations and aeration of water through the river outlet works, the Grand Canyon Monitoring and Research Center Dissolved Oxygen Model (Deemer et al. 2025) uses 8 mg/L as a conservative minimum. This 8 mg/L assumption can be seen in **Figure TA 6-11** and **Figure TA 6-12** under the Critically Dry Flow Category, where reservoir elevations fall below 3,490 feet under the No Action, Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, and the CCS Comparative Baseline. While dissolved oxygen would increase because releases from the river outlet works would effectively aerate Glen Canyon Dam releases, this assumption does not capture the infrastructure concerns

associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs, as described in **Chapter 1**, **Section 1.8.4.1.** Further, as described in **Chapter 2**, Reclamation maintains the authority to modify operations to protect Glen Canyon Dam infrastructure. Therefore, due to the limitation of long-term use of the river outlet works, a minimum annual dissolved oxygen concentration greater than 2 mg/L and elevations below 3,490 feet at Lake Powell were considered, as shown in **Figure TA 6-13**. Under these assumptions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred level of performance in 79 percent and 76 percent of futures, respectively, for the first decadal period (that is, 2027-2039). Similar to analyzing minimum dissolved oxygen concentrations alone, the simulated minimum dissolved oxygen concentrations are greater than 2 mg/L and elevations above 3,490 feet at Lake Powell in the fewest number of futures under the CCS Comparative Baseline, and Basic Coordination Alternative. The No Action, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives meet the preferred level of performance in 20 percent, 34 percent, and 44 percent of futures, respectively.

Figure TA 6-12
Dissolved Oxygen Concentration in Glen Canyon Dam Releases: Robustness. Percent of futures in which the minimum annual dissolved oxygen concentration is greater than the value specified in each row in at least 90 percent of years

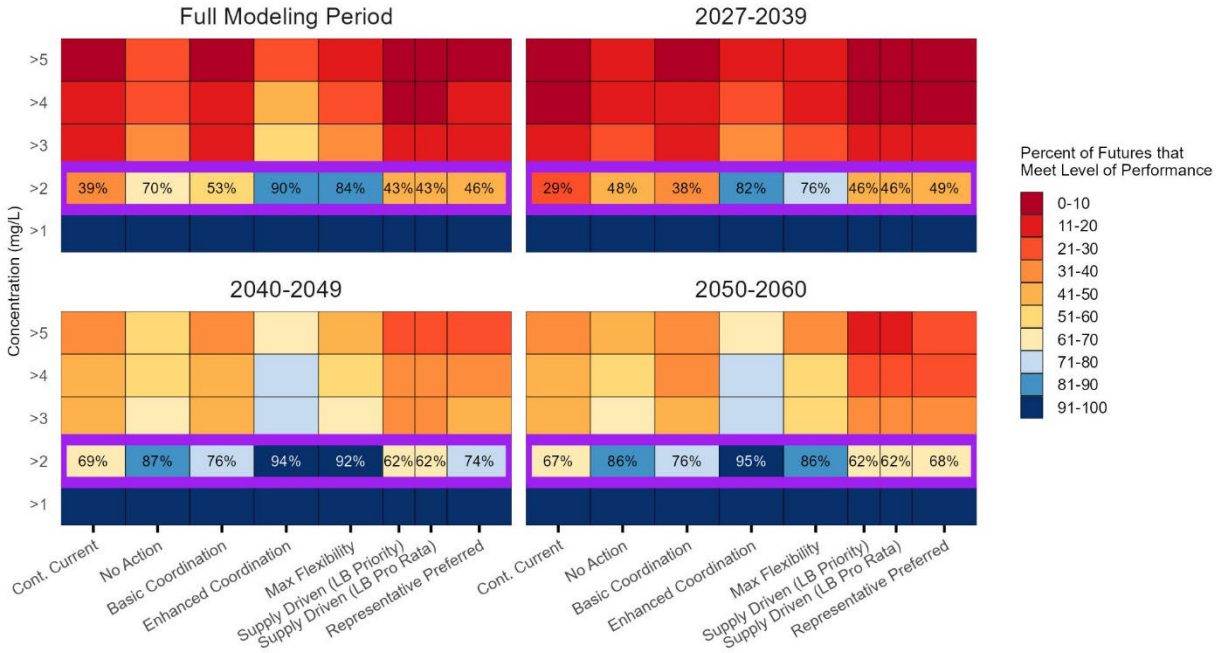


Figure TA 6-13
Lake Powell 3,490 and Dissolved Oxygen Concentration: Robustness. Percent of futures in which Lake Powell elevation stays above 3,490 feet and the minimum annual dissolved oxygen concentration is greater than the value specified in each row in at least 90 percent of years

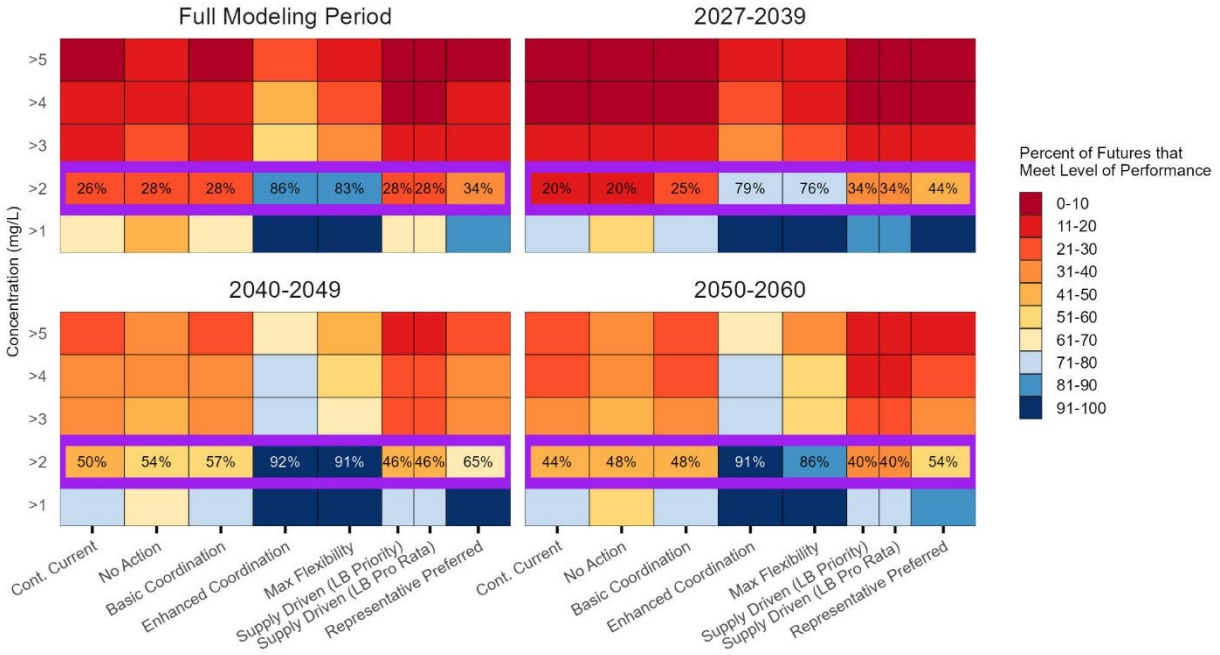


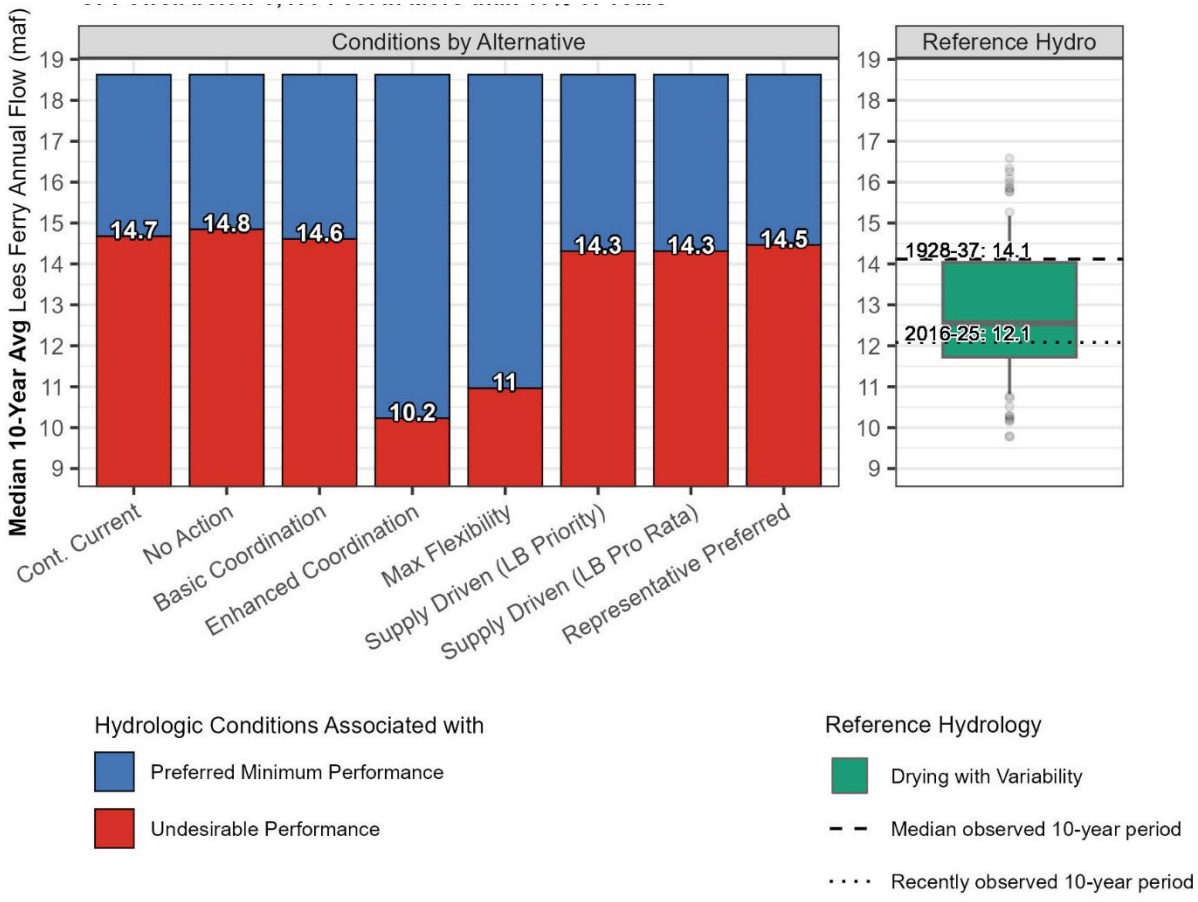
Figure TA 6-14 highlights the preferred minimum performance level of minimum annual dissolved oxygen concentrations released from Glen Canyon Dam less than 2 mg/L or Lake Powell elevation below 3,490 feet, because 2 mg/L is considered hypoxia in most streams and rivers (Blaszczak et al. 2023) and there is a limitation to long-term use of the river outlet works at Lake Powell elevations below 3,490 feet. To identify hydrologic conditions that could cause undesirable performance, the incidence of minimum dissolved oxygen less than 2 mg/L or Lake Powell elevation below 3,490 feet in more than 10 percent of years over the 34-year modeling period was analyzed.

The median 10-year average Lees Ferry natural flow was identified as a good predictor of undesirable performance. The reference hydrologic panel shows the range of median 10-year average flows represented in a reference hydrology along with the median and most recently observed 10-year periods.

If a future includes a 10-year average flow of 14.1 maf or lower, the CCS Baseline and the No Action, Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives indicate undesirable performance. About 75 percent of the reference hydrologic traces include averages this low or lower. Therefore, the hydrologic conditions associated with undesirable performance for these alternatives fall within a majority of hydrologic conditions that have already been observed.

As shown on **Figure TA 6-14**, the Enhanced Coordination Alternative would be vulnerable if the median 10-year-average Lees Ferry flow was 10.2 maf or drier, and the Maximum Operational Flexibility Alternatives would be vulnerable if the median 10-year-average Lees Ferry flow was 11 maf or drier. These conditions are drier than 90 percent of the traces in the Drying with Variability Ensemble and below recently observed 10-year-average flow; therefore, these alternatives have low vulnerability.

Figure TA 6-14
Lake Powell 3,490 and Dissolved Oxygen Concentration: Vulnerability. Conditions that Could Cause Dissolved Oxygen Concentration Less than 2 mg/L or Powell below 3,490 Feet in More than 10 percent of Years.



The Representative Preferred Alternative is likely to be vulnerable if the median 10-year-average Lees Ferry flow is 14.5 maf or less. Compared to the historical periods shown in the reference hydrologic panel, this flow has occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, more than 75 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

TA 8.2.3, in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, describes dissolved oxygen impacts on fish. The section also presents dissolved oxygen concentration thresholds of less than 3 mg/L, which can lead to reduced survival and feeding efficiencies, and of 6–9 mg/L, which are optimal for growth and survival at all life stages. Analysis of simulated minimum annual dissolved oxygen concentrations under various hydrologic scenarios shows that, in the Wet Flow Category, the median dissolved levels are similar across all alternatives, generally falling between 7 and 8 mg/L (see **Figure TA 6-11**). However, as shown on **Figure TA 6-13**, Lake Powell elevations stay above 3,490 feet and the simulated minimum annual dissolved oxygen concentration is greater than 3 mg/L in at least 90 percent of the years in a majority of futures under the Enhanced Coordination Alternative; this occurs under the other alternatives in less than 50 percent of futures, which is critical for survival and feeding efficiencies of fish. See **TA 8.2.3**, in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, for more information on the impact of dissolved oxygen on fish.

Analysis key takeaways:

- Under the Wet Flow Category, the alternatives have similar simulated median dissolved oxygen at Lees Ferry. Under drier conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives generally have higher simulated minimum annual dissolved oxygen concentrations than the other alternatives when considering futures in which Lake Powell elevations stay above 3,490 feet.
- By controlling for elevation at Lake Powell below 3,490 feet, the effect of bypass tube releases on dissolved oxygen concentrations is not captured, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the only alternatives under which simulated minimum dissolved oxygen concentrations are greater than 2 mg/L in a majority of futures (greater than 50 percent) for the full modeling period. The simulated minimum dissolved oxygen concentrations are greater than 2 mg/L in the fewest number of futures under the CCS Comparative Baseline, Basic Coordination and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives across the full modeling period.
- CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven Alternatives are vulnerable, the 10-year average Lees Ferry natural flows associated with their undesirable performance have already been observed. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are less vulnerable, with less the driest 10 percent in the Drying with Variability Ensemble below these alternatives' threshold for undesirable performance.
- Under the Critically Dry Flow Category, Lake Powell elevations stay above 3,490 feet and the simulated minimum annual dissolved oxygen concentration is greater than 3 mg/L in at least 90 percent of the years in a majority of futures under the Enhanced Coordination Alternative; this occurs under the other alternatives in less than 50 percent of futures, which is critical for survival and feeding efficiencies of fish. See **TA 8.2.3**, in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, for more information on the effect of dissolved oxygen on fish.

TA 6.2.5 Issue 4: How would reservoir storage, reservoir releases, and corresponding changes in river flows downstream of the reservoirs affect harmful algal blooms and nutrients?

Cyanobacteria blooms can alter physical and chemical water quality properties, threaten aquatic species, and release toxins into water bodies, leading to health effects for recreationists and affecting water supplies. As reservoir water levels decline, the risk of cyanobacterial blooms in reservoirs increases with more severe water level fluctuations and/or declines (Hoffman et al. 2025). However, examples also exist of no marked water quality responses to long-term water level drawdown, including Lake Mead. For example, Lake Mead reservoir has experienced dramatic multiyear reductions in water level with no apparent effects on nutrient or chlorophyll-*a* concentrations (Hannoun and Tietjen 2022). Additionally, contrary to the hypothesis that cyanobacteria would have increased throughout the reservoir, phytoplankton communicated structure remains largely stable, except for shallow areas where increases in temperature or phosphorus levels were observed (van der Nagel et al. 2025)

In **TA 3**, Hydrologic Resources, **Figure TA 3-6** shows that the water year (WY) minimum values for each alternative are similar in wetter hydrology. However, in the Average Flow Category, the Maximum Operational Flexibility and Enhanced Coordination Alternatives exhibit less variability and greater median WY minimum than the other alternatives.

Additionally, **Figure TA 3-6**, Water Year Minimum and End of Water Year Elevations and Storage Volumes of Lake Powell, in **TA 3**, Hydrologic Resources, indicates that in the Critically Dry Flow Category, the median WY minimum Lake Powell elevations are lowest amongst the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. The median WY minimum Lake Powell elevations are highest in the Enhanced Coordination and Maximum Operational Flexibility Alternatives and third highest under the Representative Preferred Alternative. The Enhanced Coordination Alternative is the only alternative under which the median WY minimum Lake Powell elevation is above 3,500 feet. Based on the latest literature review on the impact of lake levels on cyanobacteria and these simulated WY minimums, the CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would have an increased risk for cyanobacterial blooms associated with declining reservoir elevations.

In considering severe water level fluctuations as a marker of increased risk for cyanobacterial blooms in reservoirs, **Figure TA 9-7**, Robustness Heat Map showing Lake Powell maximum Annual Surface Elevation Variability in any 10-year Period, in **TA 9**, Vegetation Including Special Status Species, shows that the Enhanced Coordination and Maximum Flexibility Alternatives have the greatest number of simulated futures in which the maximum annual change in water surface elevation is less than 31.45 feet in 4 years or more out of 10 years during the first decadal period (that is, 2027-2039) compared with the other alternatives. Less severe water level fluctuations are associated with a lower risk of cyanobacterial blooms, which could indicate a decreased risk under the Enhanced Coordination Alternative compared with the other alternatives.

Key analysis takeaways:

- The CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would pose an increased risk of cyanobacterial blooms due to the lower simulated Lake Powell elevations. These increased risks would be greatest under the Critically Dry Flow Category associated with lower reservoir elevations.
- The Enhanced Coordination Alternative has the greatest number of simulated futures in which the maximum annual change in water surface elevation was less than 31.45 feet in 4 years or more out of 10 years during the full modeling period. This could decrease the risk of cyanobacterial blooms associated with severe water level fluctuations under the Enhanced Coordination Alternative compared with the other alternatives.

TA 6.2.6 Issue 5: How would reservoir storage and reservoir releases affect reservoir dilution capacity?

Generally, as reservoir elevations decrease, the dilution capacity of reservoirs like Lake Powell and Lake Mead would also decrease. Decreased dilution capacity from lower reservoir elevations could result in greater concentrations of pollutants of concern, such as PFAS. Therefore, the impacts of reservoir elevations on pollutants, such as PFAS, could be greater in the alternatives with the lowest median WY minimum reservoir elevations (see **Figure TA 3-6**, End of Water Year and Water Year Minimum Elevation and Storage Volumes of Lake Powell, in **TA 3**, Hydrologic Resources), including the CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. Quantifiable water quality impacts related to dilution capacity are not available at the time of this environmental impact statement. However, it is unlikely that any of the reservoir elevations of the alternatives would substantially reduce the dilution capacity and increase the concentration of pollutants of concern.

Key Analysis Takeaways:

- Given the current data and modeling capabilities, the impacts of the alternatives on pollutants of concern could not be quantitatively assessed. The impact of decreased dilution capacity associated with lower reservoir elevations on pollutants of concern, such as PFAS, would be greatest under alternatives with the lowest median WY minimum reservoir elevations, including the CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. However, this impact would likely be negligible since it is unlikely that any of the reservoir elevations in the alternatives would significantly reduce dilution capacity or increase the concentration of pollutants of concern.

TA 6.2.7 Summary Comparison of Alternatives

Under the Average Flow Category, the maximum simulated annual flow-weighted salinity concentrations under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives exceed the salinity threshold below Hoover Dam in one or more simulations. Simulated annual flow-weighted salinity concentrations are greatest under the Critically Dry Flow Category for all alternatives due to the low reservoir elevations associated with these hydrologic conditions.

Under the Critically Dry Flow Category, simulated average flow-weighted average salinity concentration upper extremes exceed the salinity thresholds at all sites under all alternatives. Under all alternatives, a majority (90 percent or greater) of simulated futures does not exceed the salinity criteria in even the most challenging hydrologic conditions. Therefore, no significant negative impacts on salinity are associated with any of the alternatives.

Considering the robustness of simulated salinity results, compared with the other alternatives, simulated futures under the No Action Alternative exceeds the salinity threshold below Hoover Dam under the greatest percentage of futures over the first decadal period (that is, 2027-2039). However, under all alternatives, a majority of simulated futures does not exceed the salinity criteria established by the Colorado River Basin Salinity Control Forum below Hoover Dam, below Parker Dam, or at Imperial Dam. Salinity for releases below Parker Dam and at Imperial Dam are highly correlated with releases below Hoover Dam.

In a vulnerability analysis of conditions that could cause salinity concentrations below Hoover Dam to exceed 723 mg/L, the hydrologic conditions (a 10-year drought average) associated with undesirable performance for the each of the alternatives are drier than any conditions in the observed record or 50 percent of the traces in the Drying with Variability Ensemble, so the alternatives have low vulnerability.

In the Average Flow Category, simulated annual average of daily temperatures and maximum temperatures under the Enhanced Coordination and Maximum Operational Flexibility Alternatives have a lower interquartile and overall range than the other alternatives. Under Dry and Critically Dry Flow Categories, simulated median annual average of daily temperatures and maximum temperatures and interquartile ranges increase across all alternatives, but the Enhanced Coordination Alternative has the lowest simulated median annual average of daily temperatures and maximum temperatures. CCS Comparative Baseline has the greatest annual maximum median temperature compared with the alternatives, which indicates that continuing current operations would have the potential to lead to the greatest maximum median temperature compared with all other alternatives.

The Enhanced Coordination Alternative has the greatest number of simulated futures that maintained cooler water temperatures at Lees Ferry and Pearce Ferry, which is beneficial for rainbow trout and limits smallmouth bass reproduction, but these temperatures also inhibit native fish growth and reproduction. See **TA 8.2.3**, in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, and **TA 14.2.2**, in **TA 14**, Recreation, for more detailed information on changes in water temperature from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry and impacts on rainbow trout and other sport fish, native Grand Canyon fishes, and nonnative predatory fish.

The CCS Comparative Baseline and the No Action, Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would pose an increased risk of cyanobacterial blooms due to the lower simulated Lake Powell elevations. These increased risks are more exaggerated under the Critically Dry Flow Category associated with lower reservoir elevations. The Enhanced Coordination Alternative had the greatest number of simulated futures in which the maximum annual change in water surface elevation was less than 31.45 feet in 4 years or more out of

10 years during the first decadal period (that is, 2027-2039). This could decrease the risk for cyanobacterial blooms associated with severe water level fluctuations under the Enhanced Coordination Alternative compared with the other alternatives.

Overall, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have the best performance for dissolved oxygen under median 10-year average Lees Ferry annual flow and better relative maximum and average Colorado River temperature at Lees Ferry compared with the other alternatives. These alternatives also have slightly higher flows associated with hydrologic conditions associated with undesirable performance compared with the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches); however, undesirable performance for the Enhanced Coordination and Maximum Operational Flexibility Alternatives are still lower than 25 percent of hydrologic conditions that have already been observed.

TA 6.2.8 Statistical Summary Table

Table TA 6-2
Annual Flow-Weighted Average Salinity Concentrations Below Hoover Dam*

Alternative	Flow Category (maf)	Maximum** (mg/L)	90 percent*** (mg/L)
CCS Comparative Baseline	12.0-14.0 (Average Flow)	730	609
CCS Comparative Baseline	10.0-12.0 (Dry Flow)	763	643
CCS Comparative Baseline	4.46-10.0 (Critically Dry Flow)	956	696
No Action	12.0-14.0 (Average Flow)	809	607
No Action	10.0-12.0 (Dry Flow)	897	643
No Action	4.46-10.0 (Critically Dry Flow)	1295	698
Basic Coordination	12.0-14.0 (Average Flow)	761	611
Basic Coordination	10.0-12.0(Dry Flow)	858	640
Basic Coordination	4.46-10.0 (Critically Dry Flow)	1325	690
Enhanced Coordination	12.0-14.0 (Average Flow)	720	620
Enhanced Coordination	10.0-12.0 (Dry Flow)	810	659
Enhanced Coordination	4.46-10.0 (Critically Dry Flow)	1290	711
Maximum Operational Flexibility	12.0-14.0 (Average Flow)	708	611
Maximum Operational Flexibility	10.0-12.0 (Dry Flow)	763	644
Maximum Operational Flexibility	4.46-10.0 (Critically Dry Flow)	1111	697
Supply Driven (LB Priority approach)	12.0-14.0 (Average Flow)	722	608
Supply Driven (LB Priority approach)	10.0-12.0 (Dry Flow)	780	634
Supply Driven (LB Priority approach)	4.46-10.0 (Critically Dry Flow)	1014	667
Supply Driven (LB Pro Rata approach)	12.0-14.0 (Average Flow)	706	610
Supply Driven (LB Pro Rata approach)	10.0-12.0 (Dry Flow)	770	637
Supply Driven (LB Pro Rata approach)	4.46-10.0 (Critically Dry Flow)	989	668

*Concentrations that are shaded where simulated salinity exceeds the water quality standard below Hoover Dam (that is, 723 mg/L).
**Maximum refers to the simulated salinity concentration that is greatest under its corresponding alternative and flow category.
***90 percent refers to the simulated salinity concentration that is higher than 90 percent of the total outputs under its corresponding alternative and flow category. This means that 90 percent of the simulated salinity concentrations in this flow category and under this alternative are lower than this value.

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Technical Appendix 7

Air Quality

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
°F	degrees Fahrenheit
°C	degrees Celsius
ADEQ	Arizona Department of Environmental Quality
CAA	Clean Air Act
CCS	Continued Current Strategies
CEQA	California Environmental Quality Act
CH_4	methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRSS	Colorado River Simulation System
DAQ	Division of Air Quality
dv	Deciview
eGrid	Emissions and Generation Resource Integrated Database
EIA	United States Energy Information Administration
EPA	United States Environmental Protection Agency
g CO_2e/kWh	grams of carbon dioxide equivalent per kilowatt-hour
H_2S	Hydrogen sulfide
HAP	Hazardous Air Pollutant
kg	kilograms
km^2	square kilometers
LADWP	City of Los Angeles Department of Water and Power
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
$\mu g/m^3$	micrograms per cubic meter
MWh	megawatt-hour

N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAVD 88	North American Vertical Datum of 1988
NDEP	Nevada Division of Environmental Protection
NEI	National Emissions Inventory
NLR	National Laboratory of the Rockies
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NPS	National Park Service
O_3	Ozone
PM	particulate matter
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
Reclamation	Bureau of Reclamation
SCRD	Supplemental Control Requirements Determination
SIB	Southerly International Boundary
SO_2	Sulfur dioxide
UAC	Utah Air Conservation Act
U.S.	United States
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WRCC	Western Regional Climate Center
WY	water year

TA 7. Air Quality

TA 7.1 Affected Environment

This section presents the existing conditions, regulatory framework and applicable laws, and available existing studies and resources pertaining to air quality. The geographic scope consists of Lake Powell to Southerly International Boundary (SIB), which includes the Arizona counties of Yuma, La Paz, Mohave, Coconino, Yavapai, and Navajo; the Utah counties of Washington, San Juan, and Kane; and Clark County, Nevada. These counties encompass the direct, indirect, and cumulative effects associated with air pollutant dispersal into the atmosphere. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and carbon dioxide equivalent (CO_2e) emissions and climate trends would be analyzed for the state, which would include every major hydropower facility along the Colorado River, from Lake Powell to the SIB. The geographic scope for analysis is referred to as the "analysis area" throughout this section.

TA 7.1.1 Criteria Pollutants

The Clean Air Act (CAA) was implemented to ensure acceptable and nonhazardous air quality for the people of the United States (U.S.) Subsequently, the U.S. Environmental Protection Agency (EPA) established the National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment, referred to as criteria pollutants (**Table TA 7-1**). Unlike the rest of the criteria pollutants, ground-level ozone is typically not directly emitted into the atmosphere from an emissions source. Instead, ozone is formed when emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) mix in the presence of sunlight. **Table TA 7-1** shows the current primary and secondary NAAQS and averaging period for each pollutant. Primary standards are set to protect the public health with a margin of safety, and secondary standards are meant to protect environmental concerns such as air quality related values, which are resources that may be adversely affected by a change in air quality (visibility, vegetation, water quality, soils, fish and wildlife, etc.). The applicable NAAQS have fully been adopted by Utah, Arizona, and Nevada (Clark County Division of Air Quality [DAQ] jurisdiction) and are provided in **Table TA 7-1**.

In addition, each state implements regulations that further govern fugitive dust. In Arizona, Arizona Administrative Code (Title 18, Chapter 2), enforced by the Arizona Department of Environmental Quality (ADEQ), applies to owners and operators of nonresidential construction sites in designated Dust Visibility Protection Areas and requires dust controls, vehicle speed limits and monitoring and recordings. Utah rules that address fugitive dust and particulate matter (PM) include Title R307 of the Utah Administrative Code, which applies to all new or existing sources of fugitive dust greater than one-fourth acres in size and are also in areas designated as nonattainment or maintenance for the federal PM_{10} and $PM_{2.5}$ standards. Title R307 also applies statewide outside nonattainment or maintenance areas and establishes minimum work practices and emission standards for fugitive dust. Fugitive dust controls for Nevada are outlined in Nevada Administrative Code 445B.22037. These

include best practical methods pertaining to fugitive dust and the requirement to obtain a surface disturbance operating permit for disturbance of 5 acres or more of land. These measures are generally adopted by permit conditions or compliance agreements with the Nevada Division of Environmental Protection (NDEP) and apply to regulated activities that can generate dust.

Table TA 7-1
National Ambient Air Quality Standards

Criteria Pollutant	Averaging Period	Primary NAAQS	Secondary NAAQS
Nitrogen Dioxide (NO_2)	1 hour	0.100 ppm*	N/A
	Annual	0.053 ppm†	0.053 ppm†
Sulfur Dioxide (SO_2)	1 hour	0.075 ppm‡	N/A
	3 hours	N/A	0.50 ppm§
	24 hours	N/A	N/A
	Annual	N/A	10 ppb††
Particulate Matter with a diameter of 10 microns or less (PM_{10})	24 hours	150 µg/m^3 #	150 µg/m^3 #
	Annual	N/A	N/A
Particulate Matter with a diameter of 2.5 microns or less ($PM_{2.5}$)	24 hours	35 µg/m^3 **	35 µg/m^3 **
	Annual	9 µg/m^3 †, ††	15 µg/m^3 †, ††
Carbon Monoxide (CO)	1 hour	35 ppm§	N/A
	8 hours	9 ppm§	N/A
Lead (Pb)	3 months	0.15 µg/m^3 ¶	0.15 µg/m^3 ¶
Ozone (O_3)	8 hours	0.070 ppm§§	0.070 ppm§§
	1 hour	N/A	N/A
Hydrogen Sulfide (H_2S)	1 hour	N/A	N/A
Visibility reducing particles	8 hours	N/A	N/A
Sulfates	24 hours	N/A	N/A
Vinyl Chloride	1 hour	N/A	N/A

Source: EPA 2025a

Note: N/A = not applicable; ppm = parts per million; ppb = parts per billion; µg/m^3 = micrograms per cubic meter/

* The standard is based on the 3-year average of the 98th percentile of the daily maximum 1-hour average.

† Annual mean value.

‡ The standard is based on the 3-year average of the 99th percentile of the daily maximum 1-hour average.

§ Not to be exceeded more than once per calendar year.

¶ Not to be exceeded.

Not to be exceeded more than once per calendar year on average over 3 years.

** The standard is based on the 3-year average of the 98th percentile of the 24-hour average.

†† The standard is based on the 3-year average of the weighted annual mean.

‡‡ The standard is 9 ppm for areas with an elevation less than 5,000 feet above mean sea level.

§§ The standard is based on the annual fourth-highest daily maximum 8-hour concentration averaged over 3 years.

¶¶ 30-day average.

For each criteria pollutant, the EPA classifies areas as in "attainment" if the area is in compliance with NAAQS or as "nonattainment," if one or more NAAQS is exceeded. Areas for which available data are not sufficient to make an attainment status designation are listed as unclassifiable. Air quality within the Arizona counties of La Paz, Mohave, Coconino, Yavapai, and Navajo is considered in "attainment" or "unclassifiable" for Carbon Monoxide (CO), lead, Nitrogen Dioxide

(NO_2), ozone (O_3), PM_{10}, $PM_{2.5}$, and Sulfur Dioxide (SO_2). Air quality within the Arizona county of Yuma has been designated as marginal nonattainment for the 2015 eight-hour O_3 standard, moderate nonattainment for PM_{10}, and considered in "attainment" or "unclassifiable" for all other pollutants. Air quality within the Utah counties of Washington, Kane, and San Juan is considered in "attainment" or "unclassifiable" for CO, lead, NO_2, O_3, PM_{10}, $PM_{2.5}$, and SO_2. Clark County, Nevada has been designated as serious nonattainment for the 2015 eight-hour O_3 standard and a maintenance area for CO and PM_{10}, and considered in "attainment" or "unclassifiable" for all other pollutants (EPA 2025b).

Therefore, the General Conformity Rule, which is designed to protect ambient air quality within nonattainment and maintenance areas against further degradation, would apply for O_3, CO, and PM_{10}. The general conformity de minimis thresholds for all pollutants pursuant to 40 CFR 93.153 (b)(1) are presented in **Table TA 7-2**.

Table TA 7-2
General Conformity De Minimis Levels

	Tons/Year	Nonattainment Area	Analysis Area Nonattainment
O_3 (VOCs or NO_x)	100	Other outside an ozone transport region	N/A
O_3 (VOCs or NO_x)	50	Serious	Clark County, NV
O_3 (VOCs or NO_x)	25	Severe	N/A
O_3 (VOCs or NO_x)	10	Extreme	N/A
SO_2 or NO_2	100	All	N/A
CO	100	All Maintenance Areas	Clark County, NV
PM_{10}	100	Moderate	Clark County, NV (maintenance)
PM_{10}	70	Serious	N/A
$PM_{2.5}$ (direct emissions, SO_2, VOCs, NO_x, ammonia)	100	Moderate	N/A
$PM_{2.5}$ (direct emissions, SO_2, VOCs, NO_x, ammonia)	70	Serious	N/A

Source: EPA 2025c
Notes: VOC = volatile organic compound

TA 7.1.2 Hazardous Air Pollutants

CAA regulations also control the release of hazardous air pollutants (HAPs): chemicals that are known or suspected to cause cancer or other serious health effects, such as reproductive effects, birth defects, or adverse environmental effects. EPA currently lists 187 compounds as HAPs, including benzene, toluene, and formaldehyde, which may be emitted from oil and gas development operations but are generally minimal in solar development operations. NAAQS have not been set for HAPs; rather HAP emissions are controlled by source type– or industrial sector–specific regulations by developing standards for controlling emissions of air toxics known as maximum achievable control technology standards. There are no project-specific applicable maximum

achievable control technology requirements regarding HAPs, as these standards only apply to stationary sources within specific industrial groups.

TA 7.1.3 Existing Conditions

Air Quality Monitors and Design Values

Criteria pollutants are monitored throughout various parts of the country. Monitors measure concentrations of pollutant in the atmosphere, and the results are often presented in parts per million (ppm) or micrograms per cubic meter ($\mu g/m^3$). Pursuant to 40 CFR 58.14 (c)(1), the EPA and states periodically analyze and review monitor locations, discontinue monitoring at locations where pollutant concentrations have been well below the standards, and add monitors in areas where pollutant concentrations may be approaching air quality standards. Instantaneous on-demand monitored outdoor air quality data collected from state, local, and tribal monitoring agencies can be obtained from EPA's Air Data web page and interactive tool (EPA 2025d).

The EPA uses the criteria pollutant monitoring data to determine a "design value" for each pollutant and associated averaging time. A design value is a statistic representing the monitored concentration of a given pollutant in a given location, expressed in the manner of its standard, which can be compared to the NAAQS. Design values are updated annually and posted to the EPA's Air Quality Design Value website (EPA 2025d). The most recent available 2024 design values for the analysis area counties in Arizona, Nevada, and Utah are provided in **Table TA 7-3**, **Table TA 7-4**, and **Table TA 7-5**. Rural counties may not have existing monitors; therefore, no data are available, and it is assumed that pollutant concentrations meet ambient air quality standards. Other counties may have monitors that record only certain pollutants. With the exception of Kane and San Juan Counties, criteria pollutant monitoring data are available for at least one criteria air pollutant and available criteria pollutant monitoring data are reported. Design values are typically used to designate and classify nonattainment areas, as well as to assess progress toward meeting the NAAQS. The design value for O_3 for Clark County exceeds the NAAQS for O_3 (0.70 ppm), and the number of exceedances of the PM_{10} NAAQS exceed the standard for Clark County and Yuma County. None of the other design values listed in **Table TA 7-3**, **Table TA 7-4,** and **Table TA 7-5** exceed or approach proximity to the NAAQS (EPA 2025e).

Table TA 7-3
2024 Design Values for Mohave, Coconino, Navajo, and Yavapai Counties, Arizona

Pollutant	Yuma	La Paz	Mohave	Coconino	Navajo	Yavapai	Averaging Time	NAAQS
O_3	0.069	0.068	N/A	0.065	0.064	0.061	8-hour*	0.070 ppm
NO_2	N/A	N/A	N/A	N/A	N/A	N/A	Annual†	53 ppb
NO_2	N/A	N/A	N/A	N/A	N/A	N/A	1-hour¶	100 ppb
CO	N/A	N/A	N/A	N/A	N/A	N/A	8-hour**	9 ppm
CO	N/A	N/A	N/A	N/A	N/A	N/A	1-hour**	35 ppm
SO_2	N/A	N/A	N/A	N/A	N/A	N/A	1-hour†	0.075 ppm

Pollutant	Yuma	La Paz	Mohave	Coconino	Navajo	Yavapai	Averaging Time	NAAQS
$PM_{2.5}$	8.1	3.5	N/A	N/A	N/A	N/A	Annual[§]	9 µg/m^3
$PM_{2.5}$	21	11	N/A	N/A	N/A	N/A	24-hour[¶]	35 µg/m^3
PM_{10}	6.0 2022-2024 Ave. Est. Exceed-ances	0.7 2022-2024 Ave. Est. Exceed-ances	0.7 2022-2024 Ave. Est. Exceed-ances	N/A	N/A	N/A	24-hour[††]	150 µg/m^3

Source: EPA 2025e
Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. ppb = parts per billion.
* Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years.
[†] 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
[‡] Annual fourth-highest daily maximum 1-hour concentration, averaged over 3 years.
[§] Annual mean, averaged over 3 years.
[¶] 98th percentile, averaged over 3 years.
** Not to be exceeded more than once per year
[††] Not to be exceeded more than once per year on average over 3 years.

Table TA 7-4
2024 Design Values for Washington County, Utah

Pollutant	Washington	Averaging Time	NAAQS
O_3	0.065	8-hour*	0.070 ppm
NO_2	4 ppb	Annual[†]	53 ppb
NO_2	28 ppb	1-hour[¶]	100 ppb
CO	N/A	8-hour**	9 ppm
CO	N/A	1-hour**	35 ppm
SO_2	N/A	1-hour[†]	0.075 ppm
$PM_{2.5}$	5.1	Annual[§]	9 µg/m^3
$PM_{2.5}$	14	24-hour[¶]	35 µg/m^3
PM_{10}	N/A	24-hour[††]	150 µg/m^3

Source: EPA 2025e
Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. San Juan and Kane Counties have no monitoring data.
ppb = parts per billion.
* Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years.
[†] 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
[‡] Annual fourth-highest daily maximum 1-hour concentration, averaged over 3 years.
[§] Annual mean, averaged over 3 years.
[¶] 98th percentile, averaged over 3 years.
** Not to be exceeded more than once per year
[††] Not to be exceeded more than once per year on average over 3 years.

Table TA 7-5
2024 Design Values for Clark County, Nevada

Pollutant	Clark County	Averaging Time	NAAQS
O_3	0.074 ppm	8-hour*	0.070 ppm
NO_2	20 ppb	Annual[†]	53 ppb
NO_2	51 ppb	1-hour[¶]	100 ppb
CO	2.4 ppm	8-hour**	9 ppm
CO	2.8 ppm	1-hour**	35 ppm
SO_2	4 ppb	1-hour[†]	0.075 ppm
$PM_{2.5}$	8.7 µg/m^3	Annual[§]	9 µg/m^3
$PM_{2.5}$	29 µg/m^3	24-hour[¶]	35 µg/m^3
PM_{10}	4.0 2022-2024 Average Estimated Exceedances	24-hour[††]	150 µg/m^3

Source: EPA 2025e.
Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. ppb = parts per billion.
* Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years.
[†] 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
[‡] Annual fourth-highest daily maximum 1-hour concentration, averaged over 3 years.
[§] Annual mean, averaged over 3 years.
[¶] 98th percentile, averaged over 3 years.
** Not to be exceeded more than once per year
[††] Not to be exceeded more than once per year on average over 3 years.

National Emissions Inventory

Triennially, the EPA publishes a comprehensive summary of air emissions data, known as the National Emissions Inventory (NEI). The most recent NEI data available are from 2020. **Table TA 7-6** through **Table TA 7-10** provide the 2020 emissions for the six criteria air pollutants and HAPs for the U.S.; the State of Arizona; Nevada; and Utah; and all of counties in the analysis area. The EPA uses the NEI to develop and review regulations, conduct air quality modeling, and conduct risk assessments to understand how air pollution may affect the health in communities across the country. Therefore, the nonattainment status for some of the counties in the analysis area indicate the NEI data presented below are only a concern for those pollutants in nonattainment (EPA 2023).

Table TA 7-6
National Emissions Inventory 2020 Emissions Data for U.S., Nevada, Arizona, and Utah (tons)

Pollutant	U.S.	Nevada	Arizona	Utah
NO_x	8,814,608	80,106	147,990	110,291
CO	66,065,689	412,095	1,265,343	862,864
VOC	46,140,059	267,402	680,519	465,409
PM_{10}	16,761,114	117,964	183,742	183,966
$PM_{2.5}$	5,815,036	29,738	80,611	68,285
SO_2	1,838,518	4,807	17,102	12,704
HAPs	5,964,882	57,126	114,811	83,712

Source: EPA 2023

Table TA 7-7
National Emissions Inventory 2020 Emissions Data for Nevada and Clark County (tons)

Pollutant	Nevada	Clark County	% of State
NO_x	80,106	24,426	30.5%
CO	412,095	187,398	45.5%
VOC	267,402	51,867	19.4%
PM_{10}	117,964	15,733	13.3%
$PM_{2.5}$	29,738	5,882	19.8%
SO_2	4,807	404	8.4%
HAPs	57,126	10,138	17.7%

Source: EPA 2023

Table TA 7-8
National Emissions Inventory 2020 Emissions Data for Arizona and Yuma, La Paz and Navajo Counties (tons)

Pollutant	Arizona	Yuma County	% of State	La Paz County	% of State	Navajo County	% of State
NO_x	147,990	5,792	3.9%	3,145	2.1%	8,798	5.9%
CO	1,265,343	27,492	2.1%	12,982	1.0%	21,237	1.7%
VOC	680,519	15,287	2.3%	10,727	1.6%	34,443	5.1%
PM_{10}	183,742	5,324	2.9%	2,626	1.4%	5,910	3.2%
$PM_{2.5}$	80,611	1,407	1.8%	680	0.8%	1,484	1.8%
SO_2	17,102	104	0.6%	16	0.1%	1,887	11.0%
HAPs	114,811	3,000	2.6%	1,924	1.7%	5,806	5.1%

Source: EPA 2023

Table TA 7-9
National Emissions Inventory 2020 Emissions Data for Arizona and Coconino, Mohave and Yavapai Counties (tons)

Pollutant	Arizona	Coconino County	% of State	Mohave County	% of State	Yavapai County	% of State
NO_x	147,990	12,455	8.4%	9,863	6.7%	10,411	7.0%
CO	1,265,343	102,877	8.1%	49,112	3.9%	68,627	5.4%
VOC	680,519	105,740	15.5%	37,626	5.5%	44,088	6.5%
PM_{10}	183,742	14,435	7.9%	6,384	3.5%	12,358	6.7%
$PM_{2.5}$	80,611	7,462	9.3%	2,109	2.6%	4,833	6.0%
SO_2	17,102	651	3.8%	142	0.8%	2,721	15.9%
HAPs	114,811	16,615	14.5%	7,339	6.4%	7,270	6.3%

Source: EPA 2023

Table TA 7-10
National Emissions Inventory 2020 Emissions Data for Utah and Kane, San Juan and Washington Counties (tons)

Pollutant	Utah	Kane County	% of State	San Juan County	% of State	Washington County	% of State
NO_x	110,291	791	0.7%	1,671	1.5%	3,029	2.7%
CO	862,864	7,224	6.5%	8,619	7.8%	23,078	20.9%
VOC	465,409	15,162	13.7%	20,813	18.9%	14,397	13.1%
PM_{10}	183,966	2,566	2.3%	4,206	3.8%	5,563	5.0%
$PM_{2.5}$	68,285	532	0.5%	720	0.7%	1,314	1.2%
SO_2	12,704	25	0.0%	48	0.0%	61	0.1%
HAPs	83,712	2,813	2.6%	4,025	3.6%	2,513	2.3%

Source: EPA 2023

Air Pollution Associated Diseases

Air pollution is associated with many respiratory diseases. These effects come from inhaling particulate matter, O_3, NO_X, SO_2, and other pollutants. For example, Valley Fever or coccidioidomycosis is a lung disease that is prevalent in the southwestern U.S. The fungus *Coccidioides immitis* causes Valley Fever, which grows in soils with low rainfall, high summer temperatures, and moderate winter temperatures. When the soil is disturbed by winds, construction, farming, or other activities, these fungal spores become airborne. Infection occurs when a spore is inhaled by a susceptible person or animal. Construction, agriculture, and archaeology workers are at a higher risk of exposure and disease because their jobs cause soil disturbance, which can lead to the presence of fungal spores. The analysis area counties are all areas that may harbor the fungus that causes the disease Valley Fever (CDC 2024). Depending on the level of exposure, breathing O_3 can also trigger a variety of health problems. Effects of O_3 inhalation can include coughing and sore or scratchy throat; difficulty breathing deeply and vigorously and pain when taking deep breaths; inflammation of and damage to the airways; increased susceptibility to lung infections; aggravation of lung diseases such as asthma, emphysema, and chronic bronchitis; and an increase in the frequency of asthma

attacks. Some of these effects have been found even in healthy people, but effects are more serious in people with lung diseases such as asthma. O_3 exposure may lead to increased school absences, medication use, visits to doctors and emergency rooms, and hospital admissions. Long-term exposure to O_3 is linked to aggravation of asthma and is likely to be one of many causes of asthma development. Studies in locations with elevated O_3 concentrations also report associations of O_3 with deaths from respiratory causes. Asthma often starts during childhood when the immune system is still developing. Multiple factors may work together to cause asthma. These factors include allergens in the environment that affect babies or young children, including cigarette smoke and certain germs; viral infections that affect breathing; and family history, such as a parent (in particular, a mother) who has asthma. Common triggers for asthma include indoor allergens, such as dust mites, mold, and pet dander or fur; outdoor allergens, such as pollens and mold; emotional stress; physical activity (although with treatment, most individuals can still be active); infections, such as colds, influenza (flu), or COVID-19; certain medicines, such as aspirin, which may cause serious breathing problems in people with severe asthma; poor air quality (such as high levels of O_3); or very cold air (National Heart, Lung, and Blood Institute 2024).

Prevention of Significant Deterioration and Air Quality Related Values

As set forth in the CAA, the Prevention of Significant Deterioration (PSD) regulations were developed and implemented to protect public health and welfare and to preserve, protect, and enhance the air quality in national parks, wilderness areas, monuments, and other areas of special value. The regulations apply to permitting for new or modified *major*[1] stationary sources in attainment areas. As part of the PSD, the EPA classifies airsheds as Class I or Class II. Class I areas are areas of special national or regional natural, scenic, recreational, or historic value for which the PSD regulations provide special protection. All other areas are designated Class II areas, which allow for moderate pollution increases and reasonable growth, while still applying stringent air quality constraints (NPS 2023a). Class I areas are also defined as national parks over 6,000 acres and wilderness areas and memorial parks over 5,000 acres that were established as of 1977. **Table TA 7-11** presents the Class I areas located within the analysis area, as well as those located in counties adjacent to the analysis area. For those Class I areas that are national parks, the U.S. Department of the Interior National Park Service (NPS) compiles visibility data, which are also provided in **Table TA 7-11**.

Air quality related values were established to address impacts such as acid deposition, regional haze, and the degradation of sensitive species in Class I areas.

[1] Major sources are defined as a source that emits 100 tons per year or more of any criteria pollutant for pollutants specifically listed source categories in 40 CFR 51.166(b)(a)(i)(a) or that emit 250 tons per year of any criteria pollutants and are not specifically listed sources.

Table TA 7-11
Class I Areas

State	Class I Area	Agency	County	NPS Visibility Summary
Utah	Arches National Park	USDI-NPS	Grand	Visibility is fair at Arches National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.3 dv compared to NPS visibility benchmarks. This is 2.3 dv above the estimated natural condition of 3.0 dv. In 2022, the measured visual range is between 88 and 179 miles. Without the effects of pollution, estimated visual range would be between 123 to 201 miles.
	Bryce Canyon National Park	USDI-NPS	Garfield and Kane	Visibility is fair at Bryce Canyon National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5 dv compared to NPS visibility benchmarks. This is 2.2 dv above the estimated natural condition of 2.8 dv. In 2022, the measured visual range is between 76 and 187 miles. Without the effects of pollution, estimated visual range would be between 120 to 210 miles.
	Canyonlands National Park	USDI-NPS	Wayne, Garfield, San Juan	Visibility is fair at Canyonlands National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.3 dv compared to NPS visibility benchmarks. This is 2.3 dv above the estimated natural condition of 3.0 dv. In 2022, the measured visual range is between 88 and 179 miles. Without the effects of pollution, estimated visual range would be between 123 to 201 miles.
	Capitol Reef National Park	USDI-NPS	Wayne, Garfield	Visibility is fair at Capitol Reef National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.6 dv compared to NPS visibility benchmarks. This is 2.5 dv above the estimated natural condition of 3.1 dv. In 2022, the measured visual range is between 82 and 171 miles. Without the effects of pollution, estimated visual range would be between 127 to 197 miles.

State	Class I Area	Agency	County	NPS Visibility Summary
Utah *(cont.)*	Zion National Park	USDI-NPS	Washington, Iron, and Kane	Visibility is fair at Zion National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 7 dv compared to NPS visibility benchmarks. This is 3.3 dv above the estimated natural condition of 3.7 dv. In 2022, the measured visual range is between 81 and 158 miles. Without the effects of pollution, estimated visual range would be between 122 to 203 miles.
Arizona	Petrified Forrest National Park	USDI-NPS	Apache and Navajo	Visibility is fair at Petrified Forest National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 6.4 dv compared to NPS visibility benchmarks. This is 3.5 dv above the estimated natural condition of 2.9 dv. In 2022, the measured visual range is between 86 and 161 miles. Without the effects of pollution, estimated visual range would be between 123 to 200 miles.
	Grand Canyon National Park	USDI-NPS	Coconino and Mohave	Visibility is good at Grand Canyon National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 4.8 dv compared to NPS visibility benchmarks. This is 1.9 dv above the estimated natural condition of 2.9 dv. In 2022, the measured visual range is between 100 and 194 miles. Without the effects of pollution, estimated visual range would be between 117 to 215 miles.
	Sycamore Canyon Wilderness	USDA-Forest Service	Yavapai and Coconino	N/A
	Pine Mountain Wilderness	USDA-Forest Service	Yavapai	N/A
	Mazatzal Wilderness	USDA-Forest Service	Yavapai and Gila	N/A
	Superstition Wilderness	USDA-Forest Service	Maricopa	N/A
	Sierra Ancha Wilderness	USDA-Forest Service	Gila	N/A

State	Class I Area	Agency	County	NPS Visibility Summary
Arizona *(cont.)*	Mount Baldy Wilderness	USDA-Forest Service	Apache	N/A
Nevada	Great Basin National Park	USDI-NPS	White Pine	Visibility is fair at Big Bend National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 9.8 dv compared to NPS visibility benchmarks. This is 6.1 dv above the estimated natural condition of 3.7 dv. In 2022, the measured visual range is between 58 and 140 miles. Without the effects of pollution, estimated visual range would be between 120 to 207 miles.

Source: EPA 2025d; NPS 2023a
N/A – Not available as only National Parks have a NPS Visibility Summary
dv – deciviews
USDA – U.S. Department of Agriculture
USDI – U.S. Department of the Interior

Visibility is monitored using methodologies established by the Interagency Monitoring of Protected Visual Environments Program. The particulates that contribute to haze are collected on filters at each Interagency Monitoring of Protected Visual Environments site. Samples are then measured to determine how visibility is affected over time and by which pollutants. A deciview (dv) is a unit of measurement to quantify human perception of visibility. Because visibility at any one location is highly variable throughout the year, it is characterized by three groupings: the clearest 20 percent days, average 20 percent days, and haziest 20 percent days. Visibility degradation is primarily due to sulfate, nitrate, and PM in the atmosphere, with contributions from both anthropogenic and natural sources. Measuring progress in air pollution control can be challenging, because natural sources beyond human control, such as dust storms and wildfires, can produce significant visibility impairment over large areas for days to weeks at a time. Under the 2017 Regional Haze Rule revisions, the EPA proposed a new visibility tracking metric—"most impaired days"—to better characterize visibility conditions and trends. The most impaired days are those with the most impairment from anthropogenic sources, whereas the haziest grouping now better represents days with haze from natural sources. Total haze on the most impaired days is used to track progress toward Regional Haze Rule goals. Comparing trends in the 20 percent haziest days with the 20 percent most impaired days provides a method to assess impacts from episodic events, like wildfires, which have greatly affected visibility throughout the western U.S. in recent years (Burke et al. 2021).

Visibility information can be found at the Federal Land Managers Environmental Database (FED CIRA 2023). Visibility trends for Class I areas are determined for the clearest, haziest, and most impaired categories. Visibility on the clearest days improved consistently, whereas haziest days have shown little improvement due to many years with large wildfire smoke episodes. The difference between the haziest and most impaired days has increased since the beginning of the monitoring record, indicating that episodic events are now exerting a larger impact on visibility.

Atmospheric deposition occurs when gaseous and particulate air pollutants are deposited on the ground, waterbodies, or vegetation. The NPS monitors and evaluates deposition to determine the parks that are most at risk and where conditions are declining or improving (NPS 2024). Nitrogen deposition conditions are fair to poor with no trend data available (**Table TA 7-12**). Sulfur deposition conditions are good with trend data unavailable for most locations.

Table TA 7-12
Nitrogen and Sulfur Deposition Conditions at National Parks

State	Class I Area	Nitrogen (Conditions 2018–2022/Trend 2013–2022)	Sulfur (Conditions 2018–2022//Trend 2013–2022)
Utah	Arches National Park	Poor / Trend Not Available	Good / Trend Not Available
	Bryce Canyon National Park	Fair / Relatively Unchanging	Good / Relatively Unchanging
	Canyonlands National Park	Poor / Relatively Unchanging	Good / Improving
	Capitol Reef National Park	Fair / Trend Not Available	Good / Trend Not Available
	Zion National Park	Fair / Trend Not Available	Good / Trend Not Available
Arizona	Petrified Forrest National Park	Poor / Relatively Unchanging	Good / Improving
	Grand Canyon National Park	Poor / Relatively Unchanging	Fair / Improving
Nevada	Great Basin National Park	Poor / Relatively Unchanging	Fair / Improving

Source: NPS 2023b

Historical to Present Lake Powell and Lake Mead Pool Elevations

The Lake Mead pool elevations for 1935 through 2025 are shown in **Figure TA 7-1**.

Regional Modeling and Studies

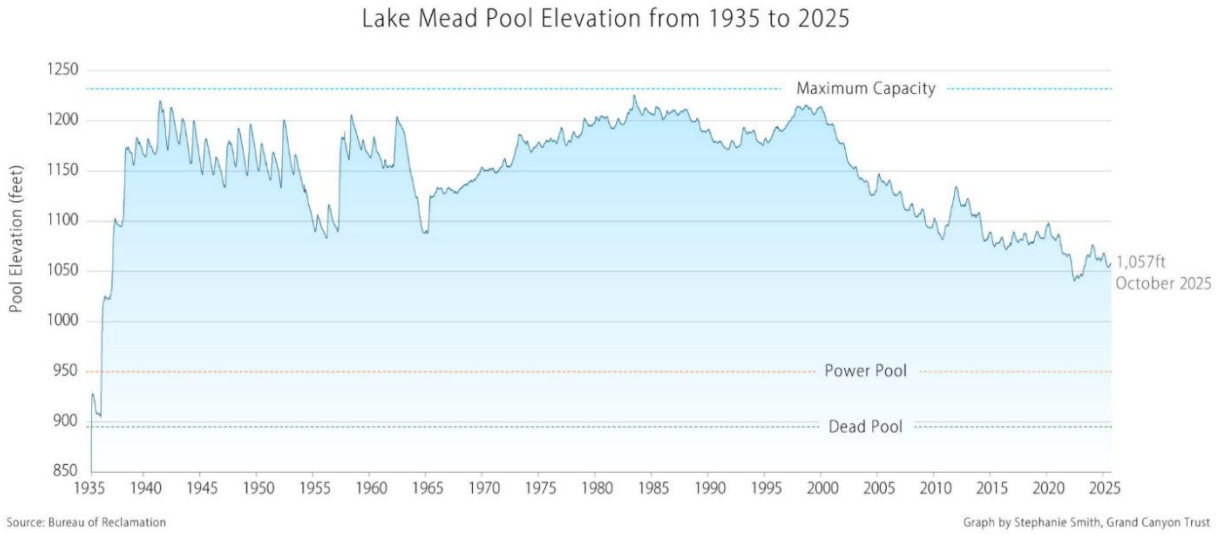
Lake Powell and Lake Mead Modeling

In 2024, U.S. Geological Survey (USGS) initiated a study in cooperation with NPS to model exposed shoreline area and potential dust emissions at Lake Powell and Lake Mead (Sankey et al. 2024).

Lake Mead Annual High and Low Elevations

Annual high and low elevations of Lake Mead for years 1935–2024 are available through the Bureau of Reclamation (Reclamation) with the maximum storage capacity at 1,229 feet. For 2024, the high elevation was 1,077 feet and the low was 1,061 feet. In 2014, the high elevation was 1,109 feet and the low was 1,080 feet (Reclamation 2025a).

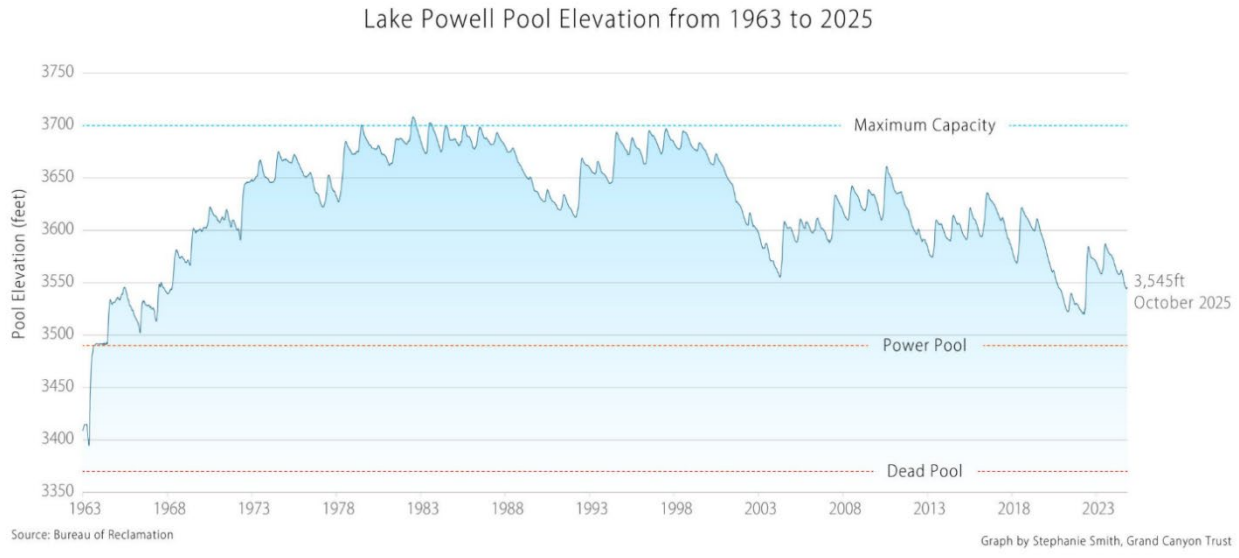
Figure TA 7-1
Lake Mead Pool Elevation from 1935 to 2025



Source: Reclamation 2026a

The Lake Powell pool elevations for 1963 through 2025 are shown in **Figure TA 7-2**.

Figure TA 7-2
Lake Powell Pool Elevation from 1963 to 2025



Source: Reclamation 2026b

Lake Powell Annual High and Low Elevations

Annual high and low elevations of Lake Powell for years 1964–2024 are available through the Reclamation with the maximum storage capacity at 3,700 feet. For 2024, the high elevation was 3,587 feet and the low was 3,558 feet. In 2014, the high elevation was 3,609 feet and the low was 3,574 feet (Reclamation 2025b).

Lake Mead Mapping

The USGS, in cooperation with the Lake Mead/Mohave Research Institute, University of Nevada, Las Vegas, completed a detailed geophysical mapping of the floor of Lake Mead during 1999, 2000, and 2001. The 1999 survey covered the Boulder Basin section of the lake, the 2000 survey focused on the northwestern portion of Las Vegas Bay, and the 2001 survey covered the eastern part of the lake. Results from these surveys have been presented in several reports. In 2003 the three datasets were integrated and presented as a composite of the entire lake in the "Mapping the floor of Lake Mead (Nevada and Arizona): Preliminary discussion and GIS data release," USGS Open-File Report 03-320. Also provided is a brief geologic overview of the floor of Lake Mead and a summary of some of the findings that have resulted from these surveys to provide a geologic perspective for the geographic information systems, which is also provided in this report.

Overall, analysis of the seismic-reflection data indicates that a large volume of sediment carried by the Colorado River has accumulated in Lake Mead since impoundment in 1935. The sediment is not uniformly distributed; rather, it is concentrated in the deepest parts of the lake and covers the floors of the valleys cut by the Colorado River and the other tributary streams that originally flowed through the area (Twichell et al. 1999, 2001, 2002, and 2003). The sediment forms a continuous cover along the entire length of the pre-impoundment Colorado River valley from the eastern extremity of the survey just east of Iceberg Canyon to the Hoover Dam at the west end of the study area. Sediment also covers the floors of the larger tributary valleys that feed the Colorado River (USGS 2003).

Lake Powell Mapping

The USGS, in cooperation with Reclamation, surveyed Lake Powell between fall 2017 and spring 2018 to produce an integrated topobathymetric dataset, which comprises topographic light detection and ranging (lidar) data (land elevation) and multibeam bathymetry (bed elevation of a waterbody), for the purposes of calculating the elevation-area-capacity relationships in Lake Powell. In 2017 and 2018, the USGS and Reclamation completed extensive surveys of the reservoir utilizing high-resolution multibeam bathymetry and lidar. These data were merged into a seamless topobathymetric dataset, which was subsequently revised to calculate new elevation-area-capacity relationships. This collaborative effort provided a revised and high-resolution estimate of storage capacity in Lake Powell and an updated topobathymetric surface to support water availability studies amid prolonged drought. The report summarizes the updated elevation-area-capacity relationships, describes the surveying methods and elevation-area-capacity calculations, and provides comparisons of the updated elevation-area-capacity relationships with previous estimates.

Storage capacity and areal extent of Lake Powell were determined for a range of elevations from 3,120 to 3,717.20 feet above the North American Vertical Datum of 1988 (NAVD 88). The updated elevation-area-capacity relationships indicate Lake Powell has lost 1,833,000 acre-feet or 6.79 percent

of its storage capacity at full pool (3,702.91 feet above NAVD 88) since construction was completed in 1963 through 2018. With consideration to potential error in the topobathymetric dataset, the loss of storage capacity ranges between 1,607,000 and 2,059,000 acre-feet. The reduction in storage capacity is attributed to sedimentation at the deltas of the Colorado and San Juan Rivers. Decreases in storage capacity were largest for the reservoir at elevations above 3,600 feet above NAVD 88, which coincide with frequent reservoir elevations since the 1970s.

Historical surveys were limited by comparatively coarser survey techniques than those used for the 2017–18 topobathymetric digital elevation model, though the average annual storage loss between surveys remained similar since impoundment in 1963. With increasing demands on water in the Colorado River Basin amid a decadal-scale drought, these results provide critical information to support water resource management in Lake Powell and beyond (Root and Jones 2022).

Impact of Lost Generation at the Glen Canyon Powerplant

This report was prepared by Argonne National Laboratory and the National Renewable Energy Laboratory (now known as National Laboratory of the Rockies [NLR]) in support of an economic and financial analysis conducted for the U.S. Department of Energy's Western Area Power Administration of the loss in Glen Canyon power generation due to the environmental requirements for the years 2024 to 2027. This report presents data showing the changes in generation sources for each of the years (2024–2027). These figures show that when there is a reduction in hydropower, the replacement generation from mostly Natural Gas Fired generation (Gas Combined Cycle) generation and Gas Combustion Turbine, with a small portion also coming from coal-fired generation. However, the compensation of natural gas and coal vary by month and year (Veselka et al. 2024).

Owens Lake California Environmental Quality Act (CEQA) Initial Study

The 2011 Supplemental Control Requirements Determination (SCRD) and 2012 SCRD projects have the objective to implement dust control measures on Owens Lake to reduce emissions, in accordance with applicable laws, without increasing water commitments while, to the extent feasible, maintaining existing habitat values; maintaining aesthetics values; providing safe, limited public access; preserving cultural resources; and utilizing existing infrastructure.

The City of Los Angeles Department of Water and Power (LADWP) is currently implementing the Owens Lake Dust Mitigation Program on Owens Lake to reduce PM_{10} emissions. LADWP constructs and operates dust control measures on the lake, in compliance with orders from the Great Basin Unified Air Pollution Control District under the authority of California Health and Safety Code Section 42316, legal settlement agreements with the Great Basin Unified Air Pollution Control District, lease agreements for use of state lands (administered by the California State Lands Commission), and other regulatory approvals.

In 2014, LADWP prepared an initial study to address the impacts of construction and operation of the Owens Lake 2011 SCRD and 2012 SCRD dust control measures projects. The initial study was prepared in accordance with the CEQA, Public Resources Code Section 21000 et seq., and the State CEQA Guidelines (Title 14 California Code of Regulations Section 15000 et seq.). The initial study

serves to identify the site-specific impacts, evaluate their potential significance, and determine the appropriate document needed to comply with the CEQA.

For this project, LADWP has determined, based on the information reviewed and contained herein, that the proposed projects could potentially have a significant environmental impact. Based on this initial study, an environmental impact report is the appropriate CEQA document for evaluating the potential environmental impacts of the Owens Lake 2011 SCRD and 2012 SCRD projects. After environmental review, if the 2011 SCRD and 2012 SCRD projects are adopted, the projects may be constructed at the same time or constructed separately, or one or both projects may not be implemented, pending further legal decisions (LADWP 2014). The potential future change for Lake Powell and Lake Mead may also highlight the need for a similar dust mitigation program, should water levels decrease below 500 square kilometers (km^2) (123,553 acres), for each lake.

TA 7.1.4 NAAQS: Regulatory Framework/Applicable Laws, Regulations, Plans, and Policies

As discussed, Section 176 of the federal CAA requires federal agencies that fund, permit, or approve an activity to ensure that the activity complies with the applicable State Implementation Plan adopted to eliminate or reduce air quality violations (42 USC 7506). In order to ensure that air pollutant emissions associated with federally approved or funded activities do not exceed emission budgets established in the applicable State Implementation Plan and do not interfere with the state's ability to attain and maintain the NAAQS in areas working to attain or maintain the standard, the EPA passed federal conformity rules. The General Conformity Rule applies to all projects that are not related to transportation. According to 40 CFR 51(W), a detailed determination of the General Conformity Rule's applicability is required when federal actions or funding of non-transportation-related activities in nonattainment areas result in emissions that exceed de minimis threshold levels (EPA 2024a). Also discussed, are the PSD regulations that are developed and implemented to protect public health and welfare and to preserve, protect, and enhance the air quality in national parks, wilderness areas, national monuments, and other areas of special value.

Arizona

Air pollutant sources in Yuma, La Paz, Coconino, Yavapai, Mohave, and Navajo Counties fall under the jurisdiction of the ADEQ Air Quality Division. ADEQ operates a network of ambient air quality monitors throughout Arizona for a variety of federal and state monitoring programs. The primary monitoring objective is to measure criteria pollutants regulated under the CAA for compliance with the NAAQS. In addition, ADEQ Air Quality Division's 'Air Permits and Compliance' section issues air quality permits to industrial facilities that emit significant quantities of air pollutants to ensure that the emissions do not harm public health or cause a significant deterioration in air quality.

Nevada

The Nevada Revised Statutes Chapter 445B focuses on air pollution in Nevada. Under this, each county in the state with a population equal to or greater than 100,000 people must establish a board of county commissioners to establish and implement an air pollution control program (NRS 445B.500). In 2001, the Clark County Board of County Commissioners established the Clark County DAQ to carry out the mandated program. There are 17 counties in the state of Nevada. All but two

counties are overseen by the NDEP for the implementation of the CAA. Washoe and Clark Counties have a delegated authority by the governor of Nevada for the implementation of the CAA. The Clark County DAQ under the Clark County Department of Environment and Sustainability is responsible for administering the air pollution control program for Clark County under the provisions of the Clark County Air Quality Regulations and the EPA-approved State Implementation Plan for Clark County, Nevada (Clark County Air Quality Regulations Sections 00 through 94 as adopted in 40 CFR 52(DD)). In Nevada, the NDEP Bureau of Air Pollution Control and Air Quality Planning has primary responsibility under Nevada Revised Statutes 445B.100 through 445B.825 for managing air quality through state regulations. Within Clark County, emissions are regulated by the Clark County DAQ. Construction activities impacting greater than 0.25 acre in Clark County would require a dust control operating permit from Clark County DAQ. Projects larger than 10 acres would also require completion of a Dust Mitigation Plan Supplement for Clark County DAQ (Clark County 2023). In addition, Section 12.1 of the Clark County Air Quality Regulations requires the issuance of a Minor Stationary Source Permit for any applicable source located in Clark County that has a potential to emit a regulated pollutant that is equal to or greater than the thresholds listed in that section. Any mechanical equipment (e.g., backup generators, boilers, cooling towers) may trigger air quality "stationary source" permitting in accordance with Clark County Air Quality Regulations Section 12.1. Therefore, stationary source permits are obtained before commencing construction of any emissions unit when collectively (i.e., emissions from all emissions units in aggregate) meeting the thresholds for any of the regulated pollutants. The NDEP Bureau of Air Pollution Control and Air Quality Planning and Clark County DAQ have both been delegated authority by the EPA to implement federal programs of the CAA.

Utah

The EPA has delegated authority to Utah DAQ, under the Utah Department of Environmental Quality, for regulating air quality in all areas of Utah, with the exception of tribal lands, which remain under the authority of the EPA. The Utah DAQ has primary responsibility for managing air quality through state regulations. The Utah DAQ's responsibility is to ensure that the air in Utah meets the health and visibility standards established under the CAA. To fulfill this responsibility, Utah DAQ is required by the federal government to oversee compliance with the NAAQS statewide and visibility standards at Class I airsheds. Utah DAQ enacts rules pertaining to air quality standards, develops plans to meet federal standards, when necessary, administers emissions reductions incentive programs, issues preconstruction and operating permits to stationary sources, and enforces compliance with state and federal air quality rules. The Utah Air Conservation Act (UAC 19-2) delegates rulemaking power to the Utah Air Quality Board to promulgate rules pertaining to air quality issues. As of August 2020, Utah Department of Environmental Quality does not require a fugitive dust control plan for the analysis area. The UAC does not specifically require the development of a fugitive dust control plan in attainment areas. However, the UAC does require that operators take measures to limit PM emissions during construction and demolition activities greater than 0.25 acres in size (UAC R307-205). UAC R307-205 also requires fugitive dust to be controlled (regardless of the size or amount of acreage disturbed) to maintain a specified opacity.

Past and Present, and Projected Climate Trends and Impacts

An analysis of regional climate impacts concluded that the rate of average annual temperature increases in the southwest U.S. was among the most rapid nationally (IPCC 2021). This temperature

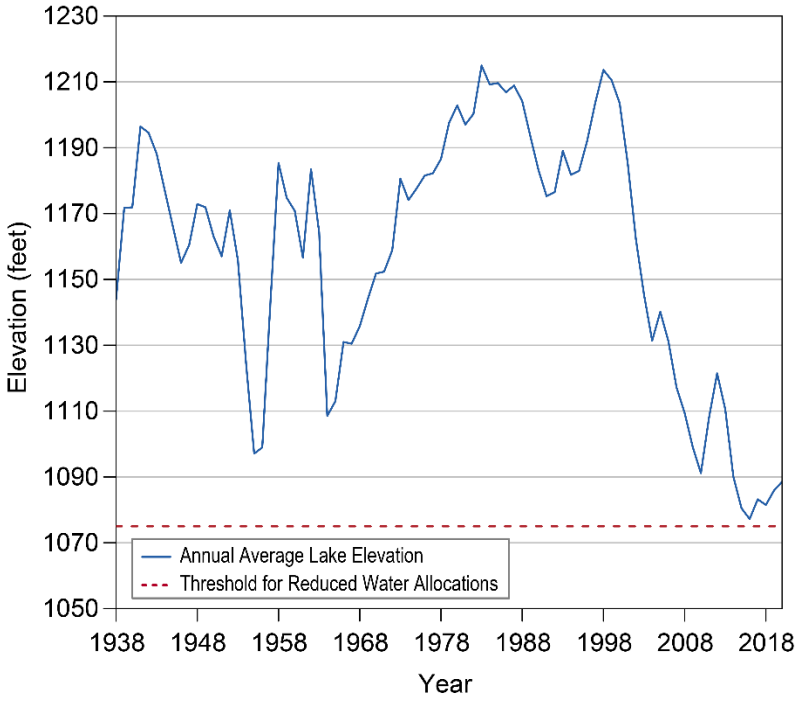
increase is causing a decline in spring snowpack and reducing flow in the four major southwest rivers. Projections of future climate trends indicate that further increases in average annual temperature could reduce precipitation. Analysis of past records and future projections indicates an overall increase in regional temperatures, including in the analysis area. The observed increase is largely the result of the warmer nights and effectively higher average daily minimum temperatures at many of the measurement sites in the region.

National Oceanic and Atmospheric Administration National Centers for Environmental Information released its climate summaries by state in 2022. The climate summaries for the analysis area states are summarized. More detailed climate discussions for each state can be found through the State Climate Summaries web page (NOAA 2022).

Arizona

Temperatures in Arizona have risen about 2.5 degrees Fahrenheit (°F; -16.4 degrees Celsius [°C]) since the beginning of the 20th century. The first 21 years of this century have been the warmest period on record for the state. The historical record indicates periodic prolonged wet and dry periods. Arizona is currently in a long-term drought that has lasted more than 20 years. Multiyear periods of high and low precipitation can cause significant variations in reservoir supplies. The latest western U.S. drought has resulted in record-low water levels in Lake Mead, which is a critical water resource for Arizona, as well as southern Nevada, southern California, and northern United Mexican States (Mexico). Since reaching high levels in the late 1990s, water levels have been falling, reaching historic lows in 2015 and 2016 (**Figure TA 7-3**). Long-term droughts also raise the risk of wildfires, already a concern for this arid state.

Figure TA 7-3
Lake Mead Water Levels at Hoover Dam



Source: Reclamation 2025a

Figure TA 7-3 shows the time series of the annual average water level (blue line) of Lake Mead at Hoover Dam from 1938 to December 2020. Water levels in Lake Mead have varied widely over the years. Low levels in the 1950s and 1960s were due to drought and the filling of Lake Powell, respectively. Recent years have seen the lowest recorded levels since the original filling of Lake Mead. The red-dashed line indicates the threshold (1,075 feet) below which a federal shortage will be declared, resulting in reduced water allocations for Nevada and Arizona. Unlike many areas of the U.S., Arizona and other southwestern states have not experienced an upward trend in the frequency of extreme precipitation events.

Under the higher and lower emissions pathways, annual average temperatures are projected to exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records.

Although projections of overall annual precipitation are uncertain, there is a risk of decreases in spring precipitation. Additionally, projected rising temperatures will raise the snow line—the average lowest elevation at which snow falls. This will increase the probability that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at lower mountain elevations that are now on the margins of reliable snowpack accumulation. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water resources needed for irrigation during the hot summer months.

Naturally occurring droughts are expected to become more intense during the cool season. Even if precipitation does not decrease, higher temperatures will intensify naturally occurring droughts by increasing water evaporation. This will further reduce streamflow, soil moisture, and water supplies. Drought will not only challenge limited agricultural resources but also increase the frequency of dust storms and the frequency of the risk of very large wildfires.

Nevada

Temperatures in Nevada have risen almost 2.4 °F (-16.4 °C) since the beginning of the 20th century. After wet conditions in the late 1990s, total annual precipitation has been near or below average since 2000 but shows no overall trend across the 126-year period of record. Seasonal precipitation patterns vary across the state, with most locations receiving the majority of their precipitation during the winter months. However, eastern and southern areas, including Clark County, can experience intense summer rainfall from the North American Monsoon system. Since 2004, the state has received multiple federal disaster declarations for wildfire events.

Drought is a critical climate threat for this arid state. Since 2000, the Colorado River Basin, the source of water for the southern part of the state, has experienced drought conditions, with impacts on Lake Mead. In addition, winter precipitation was well below average from the 2011–12 through the 2014–15 water years (WYs; October–September), and all of those years were abnormally warm. This led to a strain on water supplies in agricultural areas that rely on surface water. The majority of the counties in the state have been designated as natural disaster areas due to extreme drought conditions. Lake Mead, the largest man-made reservoir in the U.S., provides water for southern Nevada, as well as Arizona, southern California, and northern Mexico. As of October 25, 2021,

water storage in Lake Mead was at 34 percent capacity, and water levels have been dropping since 2000 (**Figure TA 7-3**). Due to aggressive conservation policies, metropolitan areas have been able to manage the reductions in water supplies. Parallel declines in snowpack have been observed over this same time period (**Figure TA 7-3**). Snowpack refills Lake Tahoe every spring, and lake levels slowly decrease throughout the year. Warm and/or dry years lead to low snowpack and associated decreases in the lake's water levels. Since 1900, the lake has fallen below the natural rim 21 times.

Under the higher and lower emissions pathway, annual average temperatures are projected to exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Extreme high temperatures are projected to increase, with potentially large impacts in the very hot southern deserts, particularly the Las Vegas metro area, where 70 percent of the state's population resides.

Projected rising temperatures in Nevada will raise the snow line—the average lowest elevation at which snow falls. This will increase the probability that precipitation will fall as rain rather than snow, reducing water storage in the snowpack, particularly at those lower mountain elevations that are now on the margins of reliable snowpack accumulation. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the already dry summer months.

Projections of annual precipitation for Nevada are uncertain throughout this century, but warmer temperatures could decrease the amount of water in the mountain snowpack and increase the demand for water. Higher temperatures will also increase the evaporation rate, which will reduce streamflow and soil moisture. Thus, the intensity of future droughts is anticipated to increase, as will the risk of wildfires in some ecosystems. Increases in population and potentially decreased water flow from the Colorado River may lead to future water security issues across the state.

Utah

Temperatures in Utah have risen more than 2.5 °F (-16.4 °C) since the beginning of the 20th century. Unlike many areas of the U.S., Utah and other southwestern states have not experienced an upward trend in the frequency of extreme precipitation events. Although floods are rare in the state, both heavy rainfall and snowmelt can result in severe flooding.

Under the higher and lower emissions pathway, annual average temperatures are projected to exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records.

Climate models are not consistent in their projections of precipitation for Utah, including winter precipitation. However, projected rising temperatures will also raise the snow line—the average lowest elevation at which snow falls. Continuing recent trends, this will increase the probability that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at lower elevations that are currently on the margins of reliable snowpack accumulation. In addition,

extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.

Droughts, a natural part of Utah's climate, are expected to become more intense. Higher temperatures will amplify the effects of naturally occurring dry spells by increasing the rate of loss of soil moisture. Most of Utah's water is supplied by the snowpack; observed trends toward more winter precipitation falling as rain and less as snow could result in less water storage. Additionally, higher spring temperatures can cause early melting of the snowpack, decreasing water availability during the already dry summer months.

TA 7.2 Environmental Consequences

This section provides an analysis of the extent and magnitude of potential impacts on air quality resources for the No Action Alternative, four action alternatives, and the Continued Current Strategies (CCS) Comparative Baseline. More detail on the alternatives can be found in **Chapter 2**, Description of Alternatives, and **Appendix S**, Additional Description of Alternatives.

TA 7.2.1 Methodology

This section examines potential effects on air quality resources under the action alternatives and the No Action Alternative, compared to the CCS Comparative Baseline. Potential impacts are considered for the following air quality resources: shoreline exposure area, fugitive dust emissions, changes in CO_2e due to hydropower, and climate trends.

To support evaluating how potential changes in reservoir water storage might affect potential dust emissions from subaerially exposed reservoir sediment, the subaerial shoreline area and potential dust emissions within Lake Powell and Lake Mead were modeled for this analysis. Methods used in this modeling combined previously published topographic and bathymetric surveys and geologic mapping (Hirschberg and Pitts 2000; Jones and Root 2021, 2022; Ferrari 2001; Root et al. 2019; Root and Jones 2022; Twichell et al. 2003; Twichell and Cross 2009; Wilson et al. 1969) with new predictions of potential dust emissions using the FENGSHA model (Mallia et al. 2017). FENGSHA is an English analog of the Mandarin term for windblown dust. Resource modeling predicts (1) the area of subaerial shoreline exposed as a function of monthly water surface elevations at Lake Powell and Lake Mead, respectively, and (2) potential dust emissions (kilograms [kg] per square meter per hour) as a function of monthly water surface elevations at Lake Powell and Lake Mead modeled using FENGSHA with sustained winds for 15 meters per second (approximately 35 miles per hour) for 6 hours. The results are presented as Glen Canyon and Lake Mead exposed shoreline area and associated emission rates (Fischella et al. 2026).

Impacts on shoreline exposure area and fugitive dust emissions are described in the following section using conditional box plots and Decision Making under Deep Uncertainty robustness heat maps and vulnerability bar plots. The conditional box plots have been developed based on the Colorado River Simulation System (CRSS) model outputs and are framed using the five flow condition categories for the preceding 3-year average Lees Ferry natural flow, as described above. In a conditional box plot, the bold center line of each box represents the median value, the top and

bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Additional background and technical details about the Decision Making under Deep Uncertainty framework are provided in **Appendix E**, DMDU Overview and Approach. Refer to **Chapter 3**, **Section 3.2.6**, for an overview of how to interpret the Decision Making under Deep Uncertainty robustness heat maps and vulnerability bar plots.

The conditional box plot for each dam compares the median CCS Comparative Baseline generation to the median generation for each alternative and multiple natural flow groups (e.g., dry, moderately dry, and normal hydrology). In each year of every modeled future, the difference in annual hydropower generation between the CCS Comparative Baseline and each alternative was computed to determine the change in generation, whether that be an increase or decrease. The annual change in generation was multiplied by the Emissions and Generation Resource Integrated Database (eGrid)/NLR emission factor to obtain the potential CO_2e for both 2025 and 2050. **Table TA 7-13** and **Table TA 7-14** shows how the 2025 and 2050 emission factors were calculated. This emission factor represents the potential CO_2e from each resource type per megawatt-hour (MWh) and the resource mix percentages for the Western Regional Climate Center (WRCC) energy production.

As time passes and more alternative resources enter the grid, energy will be produced by a different mix of resources; therefore, the 2050 emission factor in **Table TA 7-14** shows the projected mix of resources in 2050 from the U.S. Energy Information Administration (EIA) Annual Energy Outlook 2023. However, the projected mix does not take into account more recent studies that show that when there is a reduction in hydropower, the replacement generation would most likely be from natural gas.

These NLR metric tons of CO_2e per MWh and the eGrid 2023 and EIA 2050 WRCC resource mix percentages were utilized to calculate a weighted average emission factor for 2025 and 2050. The weighted emission factors are multiplied by the changes in MWh for each alternative and flow category. Analyses for other pollutants (sulfur oxide, nitrogen oxide, and particulate matter) are not included due to limitations in the emission factor data from NLR.

Impact Analysis Area

The geographic scope of the air quality resources analysis differs for each issue but includes the Lake Powell to the SIB, which includes the Arizona counties of Mohave, Coconino, Yavapai, and Navajo; the Utah counties of Washington, San Juan, and Kane; and Clark County, Nevada. However, air pollutants tend to disperse into the atmosphere, becoming less concentrated as they travel away from a source of pollution; therefore, they cannot be confined within defined boundaries, such as county lines. Specifically, the shoreline exposure analysis area includes Lake Powell and Lake Mead. The changes in CO_2e due to hydropower generation analysis areas include Glen Canyon Glen Canyon Dam, Hoover Dam, Parker Dam, and Davis Dam. The climate trends analysis area is discussed for the western U.S.

Table TA 7-13
2025 Emission Factor Information

Units	Coal	Natural Gas	Biomass	Oil	Geothermal	Wind	Concentrating Solar Power	Hydro	Nuclear
NLR CO_2e Emission Factors for Comparison of Electrical System Energy Sources									
metric tons CO_2e/MWh	1.00	0.49	0.05	0.84	0.04	0.01	0.04	0.02	0.01
EGrid 2023 WRCC Resource Percentages									
Percentage of the mix	14.00%	35.50%	1.10%	0.10%	2.20%	10.20%	9.50%	19.80%	7.70%
Weighted 2025 Emission Factor (metric tons CO_2e/MWh)	**0.33**								

Sources: EPA 2025f; EIA 2023; NLR 2021

Table TA 7-14
2050 Emission Factor Information

Units	Coal	Natural Gas	Biomass	Oil	Geothermal	Wind	Concentrating Solar Power	Hydro	Nuclear
NLR CO_2 Emission Factors for Comparison of Electrical System Energy Sources									
metric tons CO_2e/MWh	1.00	0.49	0.05	0.84	0.04	0.01	0.04	0.02	0.01
EIA 2050 WRCC Resource Percentages									
Percentage of the mix	4.00%	20.00%	1.50%	2.00%	2.50%	22.00%	35.00%	9.00%	4.00%
Weighted 2050 Emission Factor (metric tons CO_2e/MWh)	**0.18**								

Sources: EPA 2025f; EIA 2023; NLR 2021

Assumptions

- The hydrologic resources results are direct results from the CRSS model. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation.
- NLR publishes life cycle assessments, which quantify environmental burdens from "cradle to grave" and based on several different studies, estimates CO_2e emission factors associated with each type of electricity generation. They are provided in grams of CO_2e per kilowatt-hour (g CO_2e/kWh; NLR 2021).
- The eGrid was utilized to determine the North American Electric Reliability Corporation resource mix (coal, natural gas, oil, nuclear, hydropower, biomass, wind, solar, and geothermal) for the Western Electricity Coordinating Council region, which includes the analysis area (EPA 2025f).

- EIA Annual Energy Outlook 2023 (EIA 2023) provide the potential generation mix for year 2050.
- Equivalency Calculator is used to convert emissions into concrete, understandable terms such as the annual CO_2 emissions of cars, households, and power plants (EPA 2025g).

Impact Indicators

Specific impact indicators were selected to help frame the air quality resources analysis for each of the alternatives. The following indicators were used to assess impacts:

- **Shoreline Exposure**: effects on the areas of shoreline exposure due to operational activities
- **Shoreline Dust Emissions**: effects on shoreline dust emissions due to operational activities
- **Potential change of CO_2e Emissions Due to a Fluctuation of Hydropower Generation**: effects on CO_2e emissions due to operational activities

TA 7.2.2 Issue 1: How would changing flow characteristics affect the potential exposed shoreline, fallowed agricultural lands and fugitive dust?

Changes in water storage in lakes can affect the area of shoreline sediment exposed subaerially and potentially available for aeolian transport. Lake Powell and Lake Mead are two of the largest reservoirs in the United States (U.S.). Both are formed by impoundment of the Colorado River by hydroelectric dams. Lake Mead was closed by Hoover Dam in 1935. Lake Powell was closed by Glen Canyon Dam in 1963. Both reservoirs reached maximum observed water storage (water surface elevation) in 1983. Since 2020, both reservoirs have reached minimums in water storage not observed since filling. This resource modeling evaluates how potential changes in reservoir water storage might affect potential dust emissions from subaerially exposed reservoir sediment. Relationships between potential dust emissions and water storage could be useful to evaluate air quality and related resource impacts associated with Colorado River water management decisions.

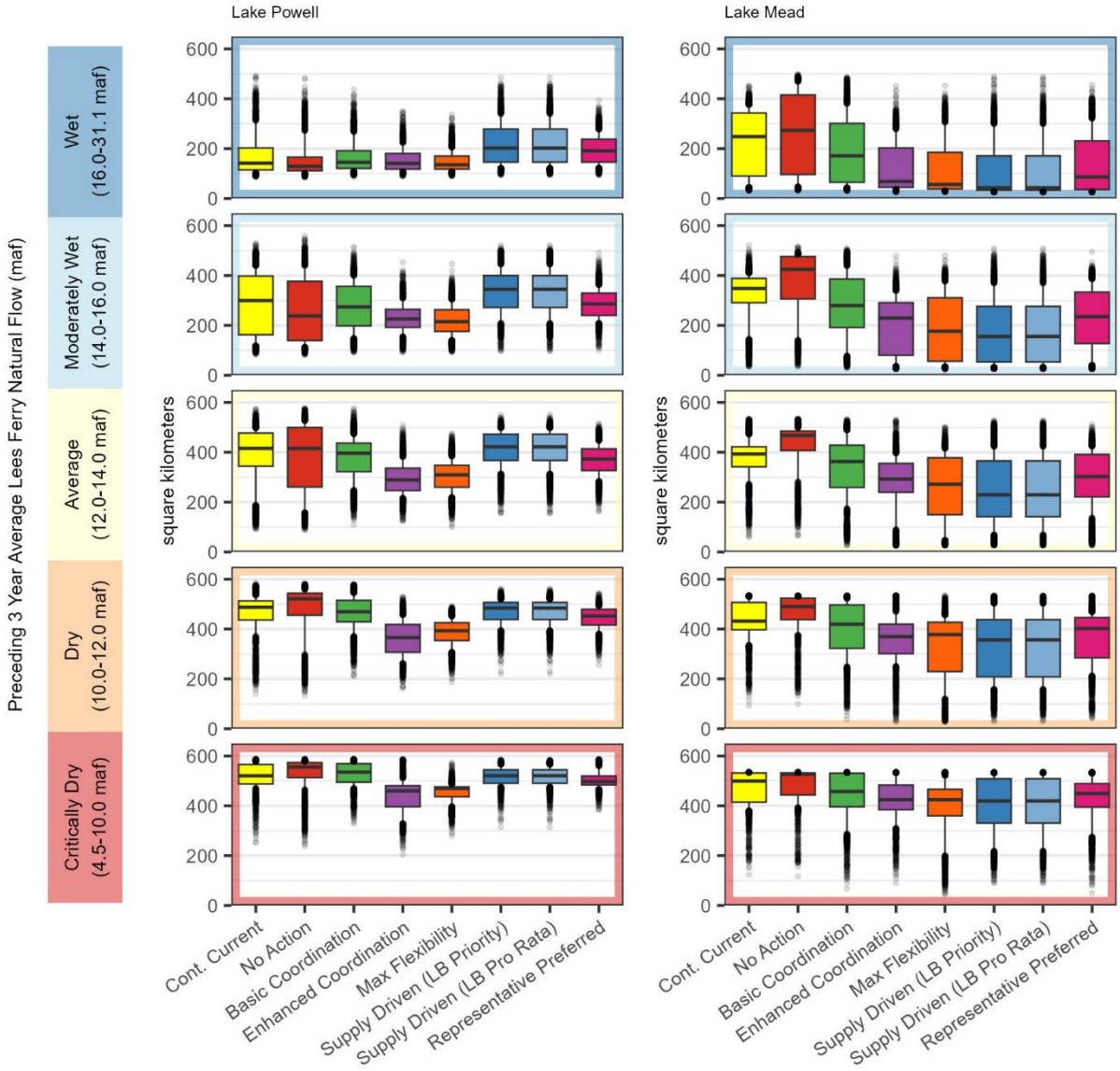
Subaerially exposed shoreline area and potential dust emissions increase as water storage decreases. However, the relationships differ at the two reservoirs due to surficial geology, deposition of reservoir sediment, and topographic and bathymetric terrain; Glen Canyon Dam impounded a deep canyon-bound segment of the Colorado River at Lake Powell, whereas Hoover Dam impounded a comparably broader valley of the river at Lake Mead.

Figure TA 7-4 shows the WY maximum exposed shoreline area for Lake Powell and Lake Mead, in km^2, broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows.

In wetter conditions, the median maximum exposed shoreline was lowest at both reservoirs across all alternatives, as higher preceding three-year average Lees Ferry flows tend to result in higher pool elevations. In the Average Flow Category, Lake Powell alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from 225 to 500 km^2 (55,598 to 123,552 acres) of maximum exposed shoreline. The CCS Comparative Baseline, as well as the No Action, Basic Coordination, Representative Preferred and Supply Driven (both Lower Basin [LB] Priority and LB Pro Rata approaches) Alternatives, all show similar medians of roughly 400 km^2 (98,842 acres) of maximum exposed shoreline. The Enhanced Coordination and Maximum Operational

Flexibility Alternatives have lower and comparable medians of about 300 km^2 (74,132 acres) of maximum exposed shoreline.

Figure TA 7-4
Water Year Maximum Exposed Shoreline Area for Lake Powell and Lake Mead (square kilometers)



The Lake Mead alternatives have varying Average Flow Category distributions, with the 25th to 75th percentiles across all alternatives spanning from 125 to 500 km^2 (30,888 to 123,552 acres) of maximum exposed shoreline. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the lowest median maximum exposed shoreline, at about 230 km^2 (56,834 acres). The No Action Alternative has the highest median value at roughly 470 km^2 (66,718 acres). The Representative Preferred Alternative has a median maximum exposed shoreline of about 300 km^2

(74,132 acres), with the 25th to 75th percentiles across all alternatives spanning from 220 to 390 km^2 (54,363 to 96,371 acres) of maximum exposed shoreline.

In the Dry Flow Category, the 25th to 75th percentiles across all Lake Powell alternatives span from approximately 300 to 545 km^2 (74,132 to 134,672 acres) of maximum exposed shoreline. The Enhanced Coordination and No Action Alternatives have the lowest and highest median maximum exposed shoreline at about 365 and 520 km^2 (90,194 and 128,495 acres), respectively. For Lake Mead, the 25th to 75th percentiles across all alternatives span from approximately 200 to 530 km^2 (49,421 to 130,966 acres) of maximum exposed shoreline. The Supply Driven (both LB Priority and LB Pro Rata approaches) and No Action Alternatives have the lowest and highest median maximum exposed shoreline at about 360 and 490 km^2 (88,598 and 121,082 acres), respectively.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Lake Powell maximum exposed shoreline, the median maximum exposed shoreline is about 450 km^2 (111,197 acres), with the 25th to 75th percentiles across all alternatives spanning from 415 to 475 km^2 (102,549 to 117,375 acres) of maximum exposed shoreline. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Powell maximum exposed shoreline, the median maximum exposed shoreline is about 495 km^2 (122,317 acres), with the 25th to 75th percentiles across all alternatives spanning from 484 to 520 km^2 (119,599 to 128,495 acres) of maximum exposed shoreline.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Lake Mead maximum exposed shoreline, the median maximum exposed shoreline is about 400 km^2 (98,842 acres), with the 25th to 75th percentiles across all alternatives spanning from 280 to 445 (69,190 to 109,962) km^2 of maximum exposed shoreline. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Mead maximum exposed shoreline, the median maximum exposed shoreline is about 450 km^2 (111,197 acres), with the 25th to 75th percentiles across all alternatives spanning from 395 to 489 km^2 (97,606 to 120,835 acres) of maximum exposed shoreline.

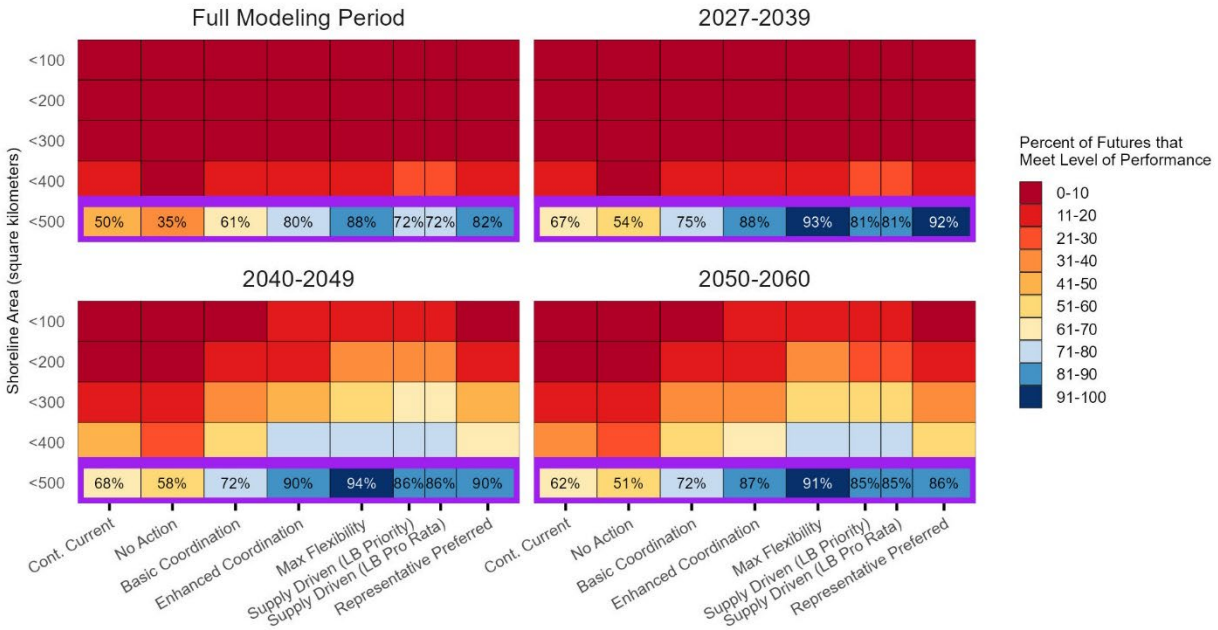
In the Critically Dry Flow Category, the median maximum exposed shoreline values for all alternatives at Lake Powell and Lake Mead are above 450 and 400 km^2 (98,842 acres and 111,197 acres), respectively. Generally, both reservoirs exhibit smaller interquartile ranges in comparison to the other flow categories. At Lake Powell, the CCS Comparative Baseline, as well as No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives show relatively similar median maximum exposed shoreline, ranging from roughly 520 to 535 km^2 (128,495 to 132,301 acres). At Lake Mead, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives display similar medians, ranging from 420 to 425 km^2 (103,784 to 105,020 acres). For all alternatives and both locations, the km^2 of maximum shoreline exposure shift higher relative to their respective medians as conditions get drier.

Lake Mead Robustness

Figure TA 7-5, below depicts the ability of each alternative to maintain Lake Mead shoreline exposure below the specified area in every month. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures in which the exposed shoreline area for each alternative remains below 500 km^2 (123,553 acres) in every month. For Lake Mead, 500 km^2 (123,553 acres) is a very rough approximation of the area of shoreline exposed when the reservoir is filled to minimum power pool (950 feet). Keeping the Lake Mead shoreline exposure below 500 km^2 (123,553 acres) ensures that fugitive dust will be minimized.

Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The color of a heat map square corresponds with the percent of futures that meet the specified level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Mead shoreline exposure area below the specified value in every month (least robust), to a dark blue color representing greater than 91 percent of futures keeping the Lake Mead shoreline exposure area below the specified value in every month (most robust).

Figure TA 7-5
Lake Mead Shoreline Area in Lake Mead National Recreation Area: Robustness. Percent of futures in which the exposed shoreline area is below the value specified in each row in every month



The comparison described here focuses on the preference to stay below 500 km^2 (123,553 acres) of exposed shoreline every month. The selected value accounts for variability, while mathematically limiting the number of instances exceeding 500 km^2 (123,553 acres), which signifies likely fugitive dust minimization.

In the full modeling period, the Enhanced Coordination, Representative Preferred, and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 80 percent, 82 percent, and 88 percent of modeled futures, respectively, which is more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meets the preferred minimum performance in 72 percent of modeled futures. The CCS Comparative Baseline, as well as No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 50 percent, 35 percent, and 61 percent of futures, respectively. Therefore, the Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 km^2 (123,553 acres) of exposed shoreline over the full modeling period. The No Action Alternative has the worst performance over the full modeling period.

In the first decadal breakout (2027 – 2039), the Representative Preferred, Maximum Operational Flexibility, and Enhanced Coordination Alternatives meet the preferred minimum performance in 92 percent, 93 percent and 88 percent of modeled futures, respectively, which is more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meets the preferred minimum performance in 81 percent of modeled futures. The CCS Comparative Baseline, as well as No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 67 percent, 54 percent, and 75 percent of futures, respectively. Therefore, the Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 km^2 (123,553 acres) of exposed shoreline over the 2027 – 2039 modeling period. The No Action Alternative has the worst performance over the 2027 – 2039 modeling period. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 92 percent of futures in the 2027-2039 modeling period.

The Representative Preferred Alternative meets staying below 500 km^2 (123,553 acres) of exposed shoreline robustness criteria in 82 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 92 percent of futures in the first modeling period.

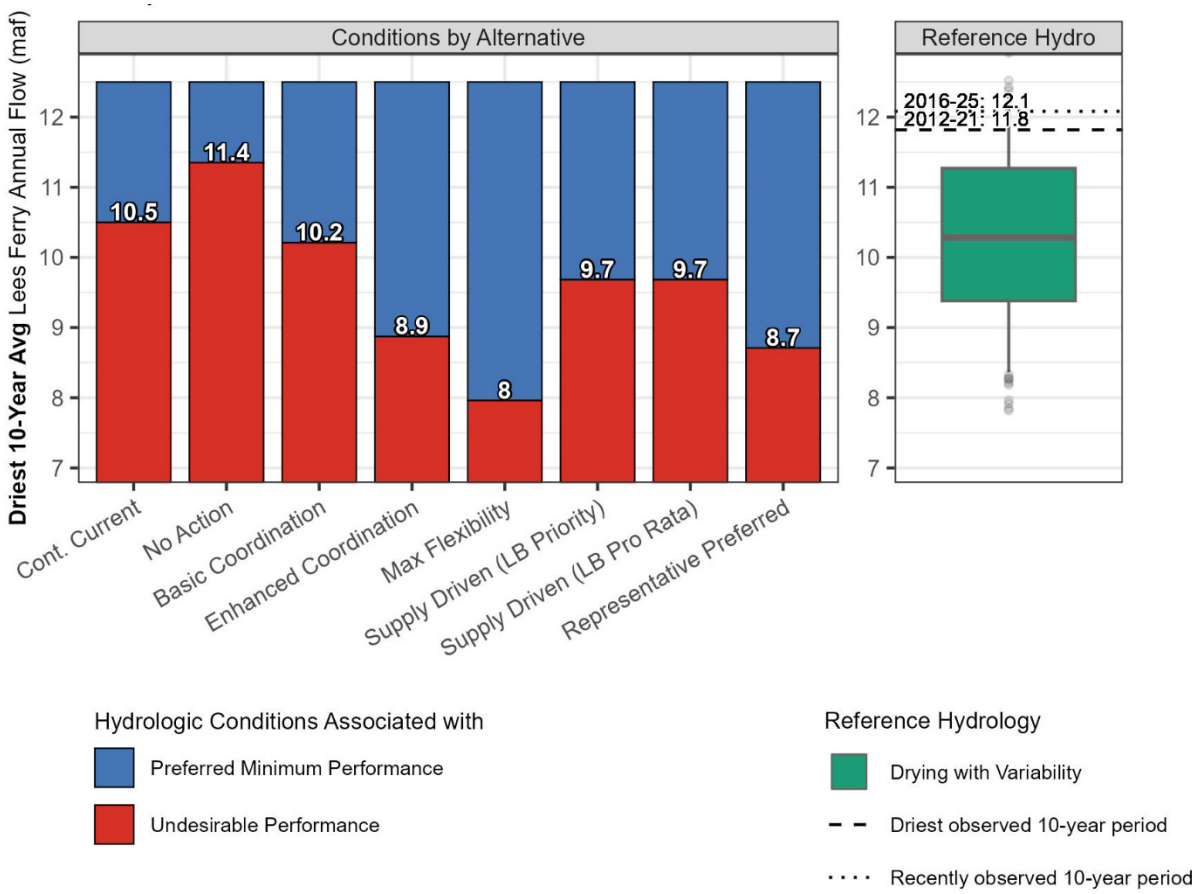
In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter time spans than over the full 34 years. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the full modeling period. The 2040–2049 modeling period generally has the most successful futures with all alternatives meeting the preferred minimum performance level in over 58 percent of futures.

Figure TA 7-6 below shows what flow conditions are likely to cause Lake Mead exposed shoreline area to exceed 500 km^2 (123,553 acres) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-5** above, which defined a future as successful when exposed shoreline area for an alternative remains below 500 km^2 (123,553 acres) in every month.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is

described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 million acre-feet [maf]) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

Figure TA 7-6
Lake Mead Shoreline Area in Lake Mead National Recreation Area: Vulnerability. Conditions that Could Cause Lake Mead Exposed Shoreline Area Above 500 Square Kilometers (123,553 acres) in One or More Months



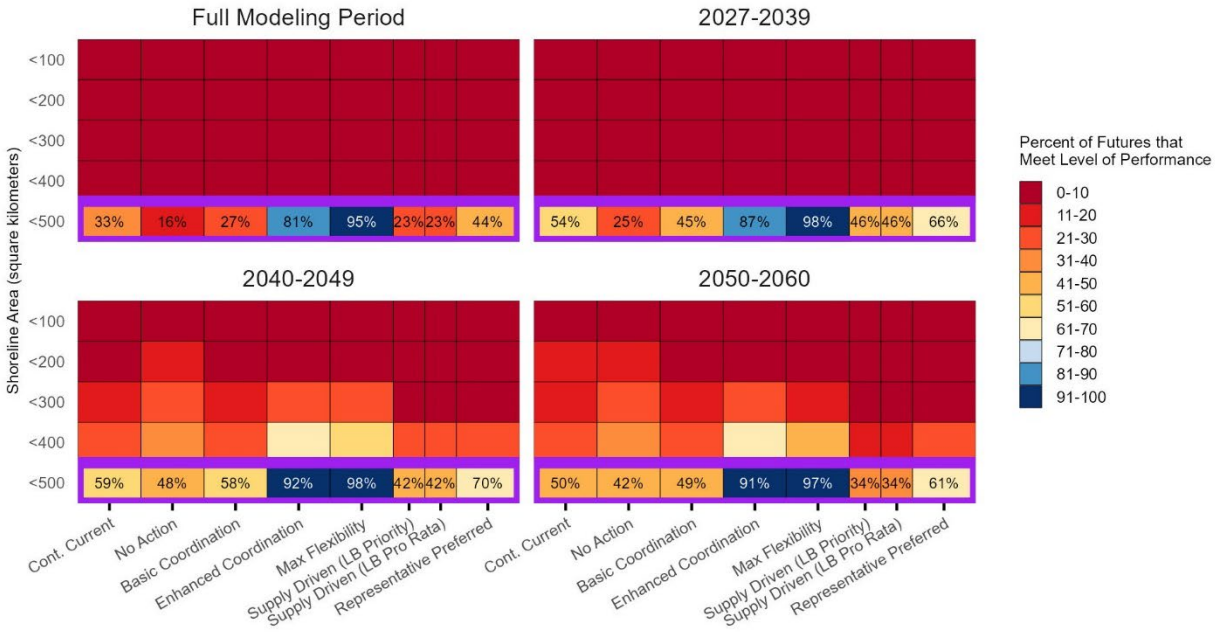
The Basic Coordination Alternative would likely be vulnerable to a Lake Mead exposed shoreline area greater than 500 km^2 (123,553 acres) under a 10-year average Lees Ferry natural flow of 10.2 maf or drier, which is slightly less vulnerable than the CCS Comparative Baseline, which is likely to be vulnerable if the 10-year average is 10.5 maf or drier. The No Action Alternative is vulnerable to a 10-year average of 11.4 maf, which is similar to the driest observed 10-year average of 11.8 maf. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven Alternatives are not likely to be vulnerable to undesirable performance unless the 10-year average flow is much drier than any observed conditions and fewer than 50 percent of the traces in the Drying with Variability ensemble include conditions that would be likely to cause vulnerability in these alternatives.

The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 8.7 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, 100 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Lake Powell Robustness

Figure TA 7-7 below depicts the ability of each alternative to maintain Lake Powell shoreline exposure below the specified area in every month. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures in which the exposed shoreline area for each alternative remains below 500 km^2 (123,553 acres) in every month. For Lake Powell, 500 km^2 (123,553 acres) is a very rough approximation of the area of shoreline exposed when the reservoir is filled to minimum power pool (3,490 feet). Keeping the Lake Powell shoreline exposure below 500 km^2 (123,553 acres) ensures that fugitive dust will be minimized.

Figure TA 7-7
Lake Powell Shoreline Area in Glen Canyon National Recreation Area: Robustness. Percent of futures in which the exposed shoreline area is below the value specified in each row in every month



Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The color of a heat map square corresponds with the percent of futures that meet the specified level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Powell shoreline exposure area below the specified value in every month (least robust), to a dark blue color representing greater than 91 percent of futures keeping the Lake Powell shoreline exposure area below the specified value in every month (most robust).

The comparison described here focuses on the preference to stay below a maximum value of 500 km^2 (123,553 acres) of exposed shoreline. The selected value accounts for variability, while mathematically limiting the number of instances exceeding 500 km^2 (123,553 acres), which signifies likely fugitive dust minimization.

In the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 81 percent and 95 percent of modeled futures, respectively. The No Action Alternative meets the preferred minimum performance in 16 percent of modeled futures. The CCS Comparative Baseline, as well as the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives meet the preferred minimum performance in 33 percent, 27 percent, and 23 percent of futures, respectively. Therefore, the Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 km^2 (123,553 acres) of shoreline exposure over the full modeling period, while the No Action Alternative has the worst performance over the full analysis period.

In the first decadal breakout (2027 – 2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 87 percent and 98 percent of modeled futures, respectively. The No Action Alternative meets the preferred minimum performance in 25 percent of modeled futures. The CCS Comparative Baseline, as well as the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives meet the preferred minimum performance in 54 percent, 45 percent, and 46 percent of futures, respectively. Therefore, the Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 km^2 (123,553 acres) of shoreline exposure over the 2027 – 2039 modeling period, while the No Action Alternative has the worst performance over the 2027 – 2039 analysis period. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 66 percent of futures in the 2027-2039 modeling period.

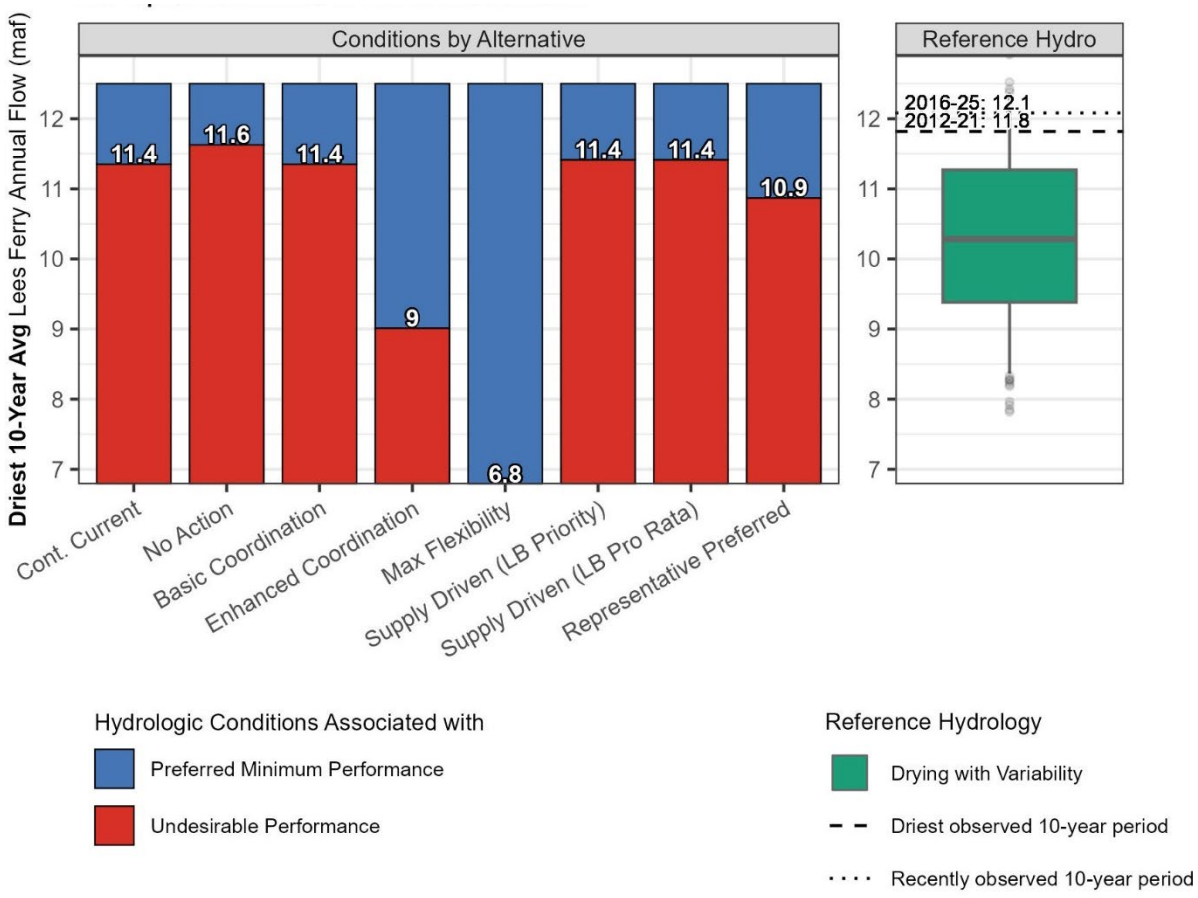
The Representative Preferred Alternative meets staying below 500 km^2 (123,553 acres) of exposed shoreline robustness criteria in 44 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 66 percent of futures in the first modeling period.

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter time spans than over the full 34 years. In the three subperiods, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum performance in more than 87 percent of futures, which is considerably more robust than the other alternatives. The robustness ranking across the three alternatives in each subperiod is largely consistent with the ranking in the full modeling period.

Figure TA 7-8 below shows what flow conditions are likely to cause Lake Powell exposed shoreline area to exceed 500 km^2 (123,553 acres) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-7** above, which defined a future as

successful when exposed shoreline area for an alternative remains below 500 km^2 (123,553 acres) in every month.

Figure TA 7-8
Lake Powell Shoreline Area in Glen Canyon National Recreation Area: Vulnerability. Conditions that Could Cause Lake Powell Exposed Shoreline Area Above 500 Square Kilometers in One or More Months



For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

If the future includes a 10-year average flow of 11.6 maf or lower, the No Action Alternative results indicate undesirable performance. The CCS Comparative Baseline, as well as the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata) Alternatives, are similar to the No Action Alternative, reaching undesirable performance when the 10-year average flow is 11.4 maf or lower. These conditions correspond to undesirable performance levels comparable to the driest observed

10-year average flow of 11.8 maf, with roughly 75 to 90 percent of the Drying with Variability traces occurring below these thresholds.

The Enhanced Coordination Alternative modeling results indicate undesirable performance at a 10-year average flow of 9 maf or drier, which occurs in less than 25 percent of the Drying with Variability traces. The Maximum Operational Flexibility Alternative is least vulnerable, with no Drying with Variability traces occurring below the undesirable performance level of 6.8 maf.

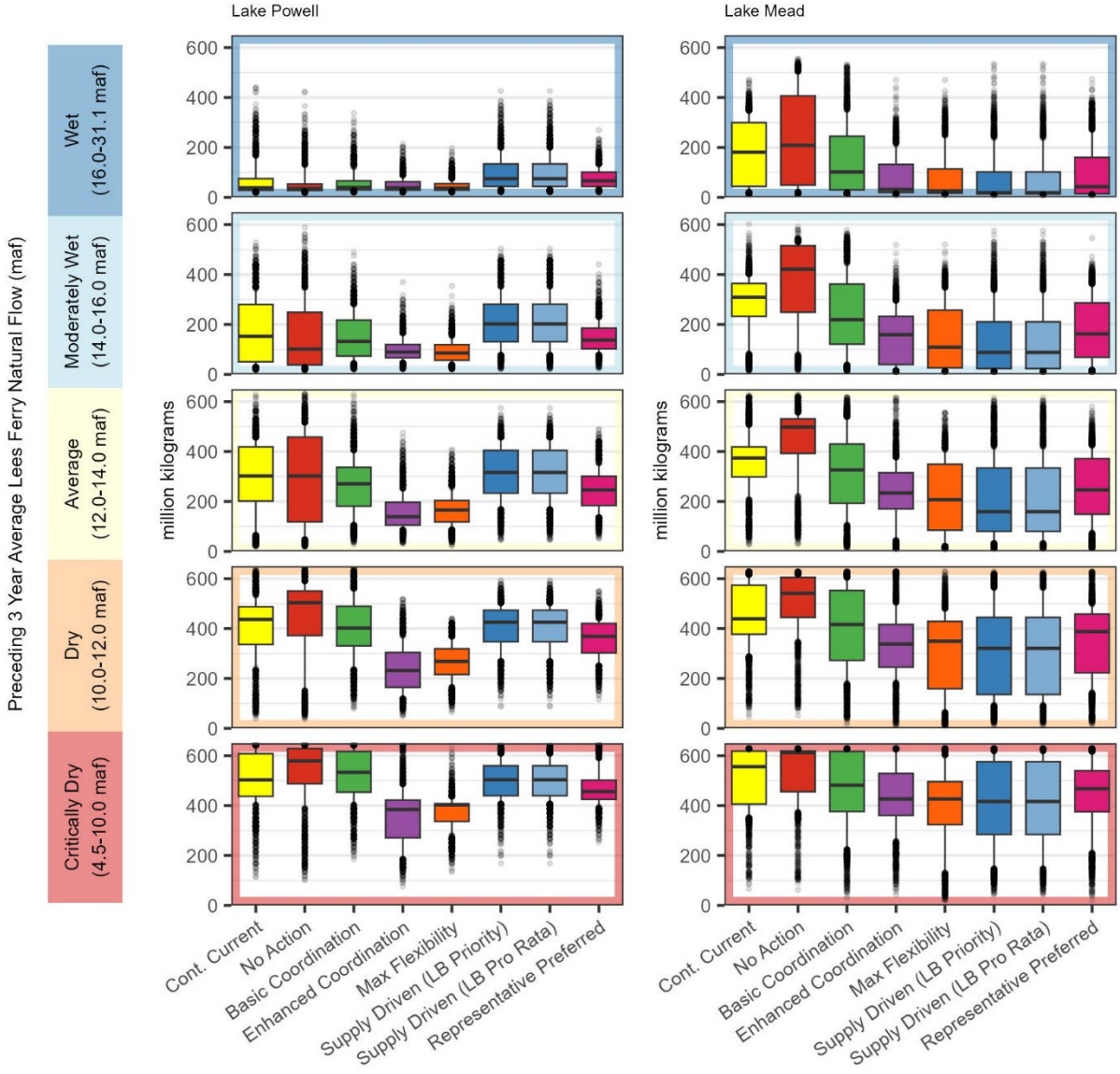
The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 10.9 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, 30 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Figure TA 7-9 shows the WY maximum monthly shoreline dust emission for Lake Powell and Lake Mead, in million kg of $PM_{2.5}$, and broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows.

In the Average Flow Category, Lake Powell alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from approximately 105 to 460 million kg (231 to 1,014 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure. The CCS Comparative Baseline, as well as No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, have similar median maximum monthly emission rates of around 300 million kg (661 million pounds) of $PM_{2.5}$ as a result of shoreline exposure, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives display lower medians of around 150 million kg (331 million pounds) of $PM_{2.5}$. The Lake Mead alternatives have varying distributions, with the 25th to 75th percentiles across all alternatives spanning from 80 to 540 million kg (176 to 1,190 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure. In comparison to Lake Powell, the median monthly emission rates are more variable for Lake Mead, with the No Action and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives displaying the highest and lowest values at about 500 and 160 million kg (1,102 and 353 million pounds) of $PM_{2.5}$, respectively.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Lake Powell $PM_{2.5}$ emissions as a result of shoreline exposure, the median $PM_{2.5}$ emissions is about 369 million kg (814 million pounds), with the 25th to 75th percentiles across all alternatives spanning from 303 to 421 million kg (668 to 928 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Powell $PM_{2.5}$ emissions as a result of shoreline exposure, the median $PM_{2.5}$ emissions is about 456 million kg (1,005 million pounds), with the 25th to 75th percentiles across all alternatives spanning from 425 to 502 million kg (937 to 1,107 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure.

Figure TA 7-9
Water Year Maximum Monthly Shoreline Dust Emissions for Lake Powell and Lake Mead (million kilograms)



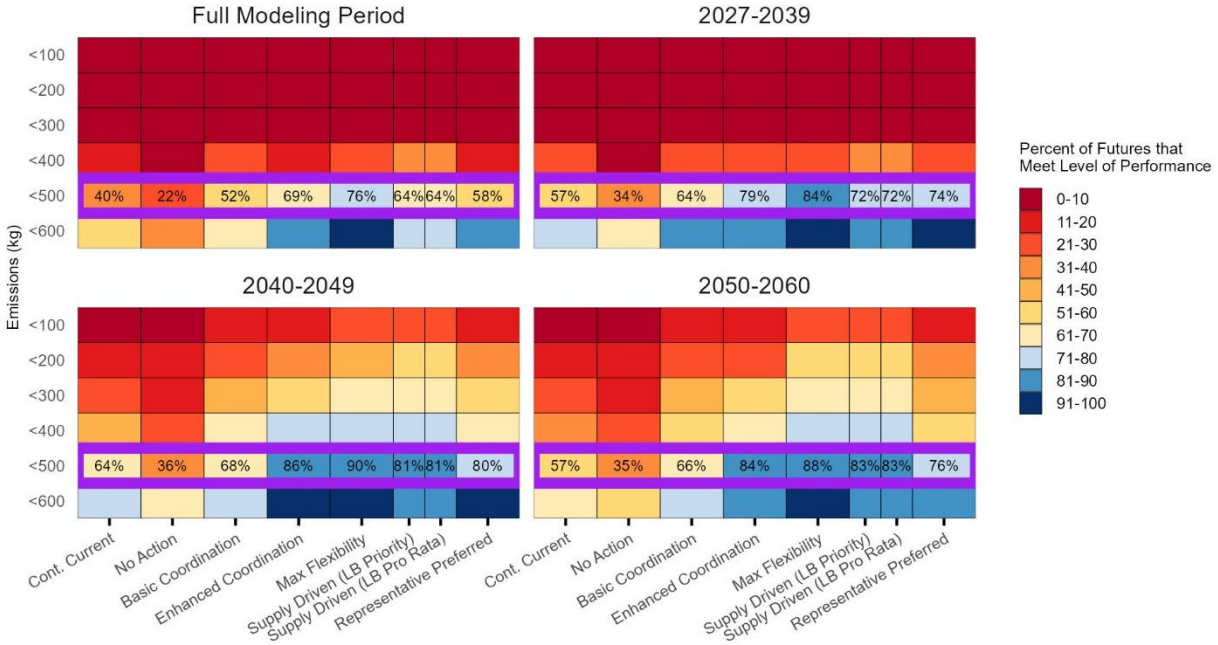
The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Lake Mead $PM_{2.5}$ emissions as a result of shoreline exposure, the median $PM_{2.5}$ emissions is about 388 million kg (855 million pounds), with the 25th to 75th percentiles across all alternatives spanning from 223 to 458 million kg (492 to 1,010 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Lake Mead $PM_{2.5}$ emissions as a result of shoreline exposure, the median $PM_{2.5}$ emissions is about 468 million kg (1,032 million pounds), with the 25th to 75th percentiles across all alternatives spanning from 375 to 540 million kg (827 to 1,191 million pounds) of $PM_{2.5}$ emissions as a result of shoreline exposure.

As conditions become wetter, the maximum monthly shoreline dust emissions show lower median rates, with the Wet Flow Category also displaying the smallest interquartile ranges. On the other hand, maximum monthly shoreline dust emissions shift higher during drier conditions when more shoreline is exposed.

Lake Mead Robustness

Figure TA 7-10, below depicts the performance of each alternative to maintain Lake Mead shoreline dust ($PM_{2.5}$) emissions below the specified value in every month. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures in which the shoreline dust emissions are less than 500 million kg (1,102 million pounds) in every month. Keeping the Lake Mead emissions below 500 million kg (1,102 million pounds) minimizes fugitive dust; therefore, protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power.

Figure TA 7-10
Lake Mead Shoreline Dust (PM 2.5) Emissions in Lake Mead National Recreation Area: Robustness.
Percent of futures in which emissions are less than the value specified in each row in every month



Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The color of a heat map square corresponds with the percent of futures that meet the specified level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Mead shoreline dust emissions below the specified value in every month (least robust), to a dark blue color representing greater than 91 percent of futures keeping the Lake Mead shoreline dust emissions below the specified value in every month (most robust).

The comparison described here focuses on the preference to stay below 500 million kg (1,102 million pounds) of shoreline dust emissions. The selected value accounts for variability, while mathematically limiting the number of instances exceeding 500 million kg (1,102 million pounds), which signifies likely fugitive dust minimization.

In the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum performance in 69 percent and 76 percent of modeled futures, respectively, which is more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can meet the preferred minimum performance in 64 percent of modeled futures. The CCS Comparative Baseline, as well as the No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 40 percent, 22 percent, and 52 percent of futures, respectively.

In the first decadal breakout (2027 – 2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum performance in 79 percent and 84 percent of modeled futures, respectively, which is more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can meet the preferred minimum performance in 72 percent of modeled futures. The CCS Comparative Baseline, as well as the No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 57 percent, 34 percent, and 64 percent of futures, respectively. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 74 percent of futures in the 2027-2039 modeling period.

The Representative Preferred Alternative meets staying below 500 million kg (1,102 million pounds) of shoreline dust emissions robustness criteria in 58 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 74 percent of futures in the first modeling period.

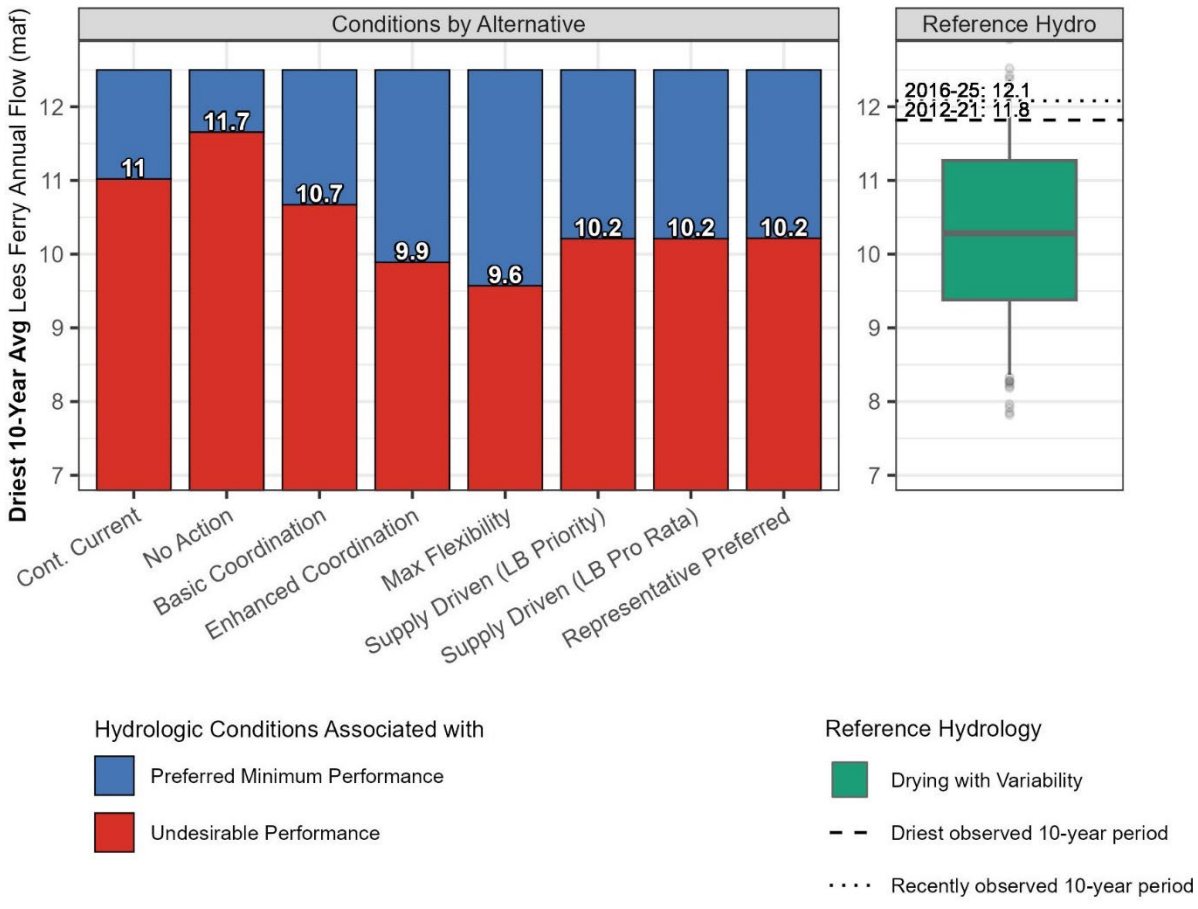
In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter time spans than over the full 34 years. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the full modeling period.

Figure TA 7-11 below shows what flow conditions are likely to cause Lake Mead shoreline dust ($PM_{2.5}$) emissions to exceed 500 million kg (1,102 million pounds) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-10** above, which defined a future as successful when shoreline dust emissions for an alternative are less than 500 million kg (1,102 million pounds) in every month.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The No Action Alternative would likely be vulnerable to undesirable shoreline dust emissions under a driest 10-year average Lees Ferry flow of 11.7 maf or drier, which is similar to the driest observed 10-year average of 11.8 maf. The CCS Comparative Baseline, as well as Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives reach undesirable performance at a driest 10-year average flow that occurs in 50 to 75 percent of the Drying with Variability traces, suggesting these alternatives are reasonably likely to be vulnerable. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are not likely to be vulnerable to undesirable performance unless the 10-year average flow is much drier than any observed conditions, and fewer than 50 percent of the traces in the Drying with Variability ensemble include conditions that would be likely to cause vulnerability in these alternatives.

Figure TA 7-11
Lake Mead Shoreline Dust (PM 2.5) Emissions in Lake Mead National Recreation Area: Vulnerability.
Conditions that Could Cause Lake Mead Emissions Above 500 million kilograms in One or More Months



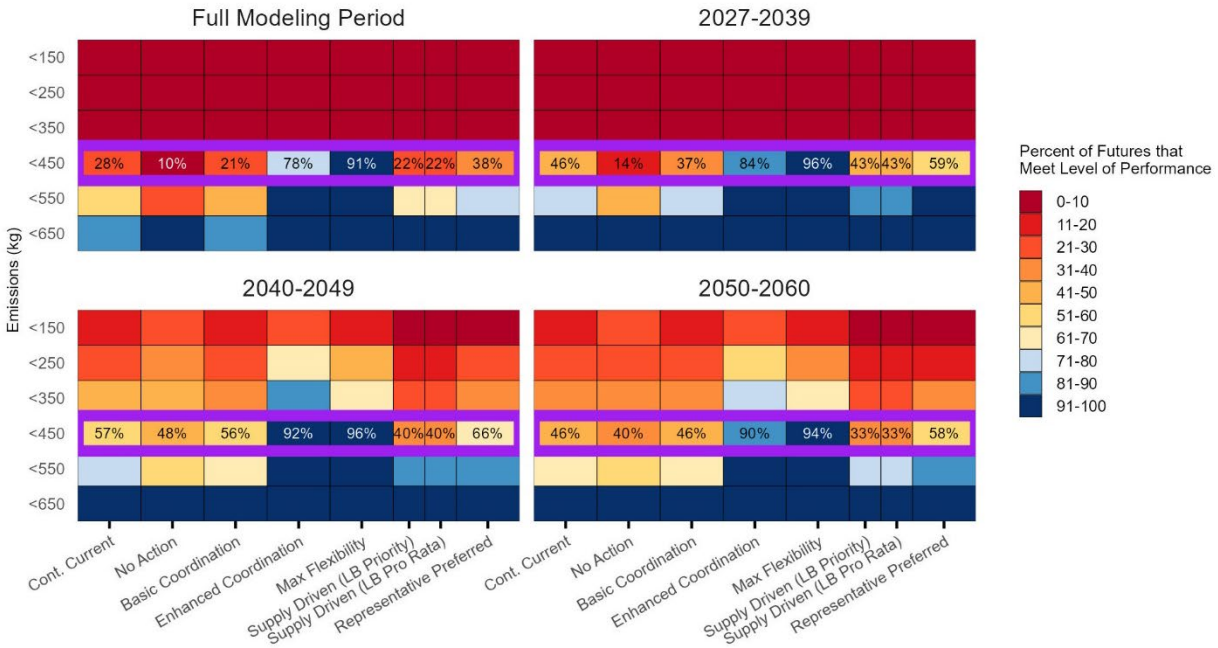
The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 10.2 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability

Ensemble that represents potential future hydrologic conditions, 20 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Lake Powell Robustness

Figure TA 7-12, below depicts the performance of each alternative to maintain Lake Powell shoreline dust ($PM_{2.5}$) emissions below the specified value in every month. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures in which the shoreline dust emissions are less than 450 million kg (992 million pounds) every month. Keeping the Lake Powell emissions below 450 million kg (992 million pounds) ensures that fugitive dust would be minimized protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power.

Figure TA 7-12
Lake Powell Shoreline Dust (PM 2.5) Emissions in Glen Canyon National Recreation Area: Robustness.
Percent of futures in which emissions are less than the value specified in each row in every month



Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The color of a heat map square corresponds with the percent of futures that meet the specified level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Powell shoreline dust emissions below the specified value in every month (least robust), to a dark blue color representing greater than 91 percent of futures keeping the Lake Powell shoreline dust emissions below the specified value in every month (most robust).

The comparison described here focuses on the preference to stay below a maximum value of 450 million kg (992 million pounds) of shoreline dust emissions. The selected value accounts for variability, while mathematically limiting the number of instances exceeding 450 million kg (992 million pounds), which signifies likely fugitive dust minimization.

In the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 78 percent and 91 percent of modeled futures, respectively, which is considerably more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can meet the preferred minimum performance in 22 percent of modeled futures. The CCS Comparative Baseline, as well as No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 28 percent, 10 percent, and 21 percent of futures, respectively.

In the first decadal breakout (2027 – 2039), the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 84 percent and 96 percent of modeled futures, respectively, which is considerably more robust than the other alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can meet the preferred minimum performance in 43 percent of modeled futures. The CCS Comparative Baseline, as well as No Action and Basic Coordination Alternatives, are only able to meet the preferred minimum performance in 46 percent, 14 percent, and 37 percent of futures, respectively. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 59 percent of futures in the 2027-2039 modeling period.

The Representative Preferred Alternative meets staying below 450 million kg (992 million pounds) of shoreline dust emissions robustness criteria in 38 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it's important to note that it meets the preferred minimum performance level in 59 percent of futures in the first modeling period.

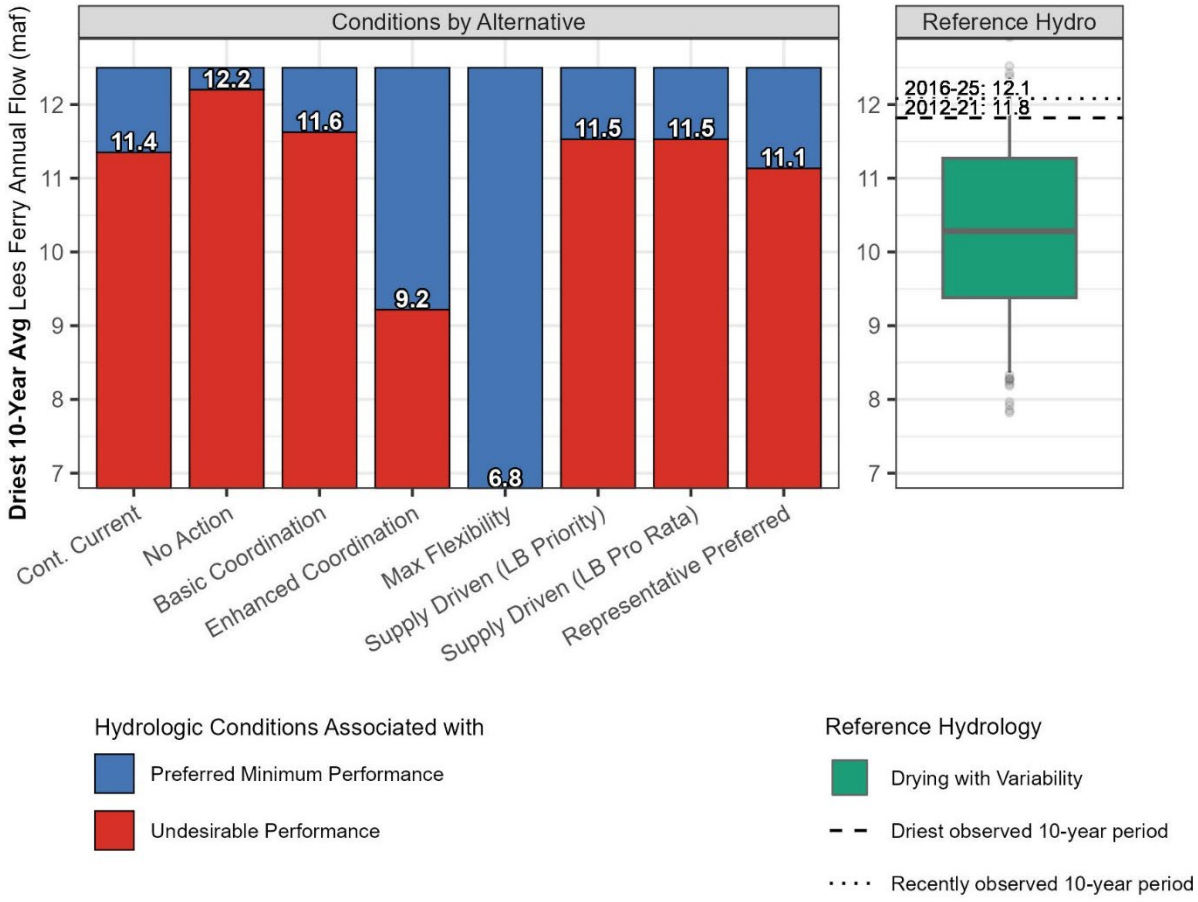
In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter time spans than over the full 34 years. In the three subperiods, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum performance in more than 80 percent of futures, which is considerably more robust than the other alternatives.

Figure TA 7-13 below shows what flow conditions are likely to cause Lake Powell shoreline dust ($PM_{2.5}$) emissions to exceed 450 million kg (992 million pounds) in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 7-12** above, which defined a future as successful when shoreline dust emissions for an alternative are less than 450 million kg (992 million pounds) in every month.

For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow

from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

Figure TA 7-13
Lake Powell Shoreline Dust (PM 2.5) Emissions in Glen Canyon National Recreation Area: Vulnerability.
Conditions that Could Cause Lake Powell Emissions Above 450 million kilograms in One or More Months



The No Action Alternative would likely be vulnerable to undesirable shoreline dust emissions under a 10-year average Lees Ferry natural flow of 12.2 maf or drier, which is similar to the recently observed 10-year average of 12.1 maf. The CCS Comparative Baseline, as well as Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, have similar results, indicating undesirable performance during a 10-year average flow ranging from 11.4–11.6 maf or lower. These results are also similar to the driest observed 10-year average flow (11.8 maf), with roughly 75 to 90 percent of the Drying with Variability traces including conditions that would be likely to cause vulnerability in these alternatives. The Enhanced Coordination Alternative modeling results indicate undesirable performance at a 10-year average flow of 9.2 maf or lower, which occurs in less than 25 percent of the Drying with Variability traces. The Maximum Operational Flexibility

Alternative is least vulnerable, with no Drying with Variability traces occurring below the undesirable performance level of 6.8 maf.

The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 11.1 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has not occurred before. Compared to the Drying with Variability Ensemble that represents potential future hydrologic conditions, 40 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

When reservoir elevations are low and there is more dust mobilization and potential acceleration of runoff, snow in locations like the Rockies could be subject to dust on snow effects. Dust darkens the snow surface, reducing its albedo (reflectivity). Clean snow reflects up to 90 percent of sunlight, but when dust is present, more sunlight is absorbed instead of reflected. As a result, snow melts faster, even if temperatures remain low. This effect is especially pronounced in spring, when the sun is stronger. This has the potential to alter water timing in the watersheds. Because snow melts earlier and faster due to dust, the rivers and streams may experience earlier peak flows. This can lead to less water availability in summer when it is most needed (e.g., for agriculture, ecosystems, and human consumption).

Changing flow characteristics can affect the fallowing of agricultural lands, especially in regions that rely on consistent irrigation from reservoirs. If the changing flows result in reduced dam releases, there could be less irrigation water available to downstream farmers. Reduced dam releases could also result in forced fallowing, which occurs when water is insufficient and farmers fallow (intentionally leave idle) some or all of their fields to conserve water for high-value crops and avoid costs associated with planting and irrigation they cannot support.

Information on potential fallowed acreage is presented in **TA 16.2.2** in **TA 16**, Socioeconomics, including **Figure TA 16-1**. As described in that section, estimates of fallowed acreage are based on simplifying assumptions regarding water availability, crop profitability, and agricultural decision-making, and are intended to support regional-scale economic analysis. These estimates are inherently uncertain and do not represent site-specific or on-the-ground predictions of fallowing patterns, which would vary based on localized conditions, such as water availability, soil characteristics, market conditions, and individual farm management decisions.

Fallowed agricultural lands may be a source of fugitive dust emissions, particularly under dry and unvegetated conditions. At a screening level, windblown dust emissions from fallow lands can be estimated using generalized emission factors derived from U.S. EPA AP-42 guidance (EPA 2026). Typical emission factors for fallow or bare agricultural lands range from approximately 0.1 to 0.5 tons of PM_{10} per acre per year, depending on site-specific conditions. Lower emissions within this range would be expected where soils are crusted, vegetated, or otherwise stabilized, while higher emissions may occur in areas with dry, loose soils and greater wind exposure, such as arid environments in the Southwest. $PM_{2.5}$ emissions are generally a fraction of PM_{10} emissions (commonly on the order of 10 to 20 percent), though this proportion may also vary.

Actual emissions from fallowed lands would depend on numerous factors not known at this programmatic stage of analysis, including soil type, surface disturbance, vegetation cover, wind

speed, and the presence or absence of dust control measures (e.g., irrigation, soil stabilizers, or conservation practices). In addition, the spatial distribution and timing of fallowing are uncertain and cannot be predicted with sufficient specificity to support detailed emissions modeling. Therefore, while the emission factor range provided above offers a general indication of the potential magnitude of fugitive dust emissions, it should be considered a screening-level approximation only.

Clark County, Nevada is the only county in the analysis area that has been designated as serious nonattainment for the 2015 eight-hour O_3 standard and a maintenance area for CO and PM_{10} (EPA 2025b). In addition, the design value for O_3 for Clark County exceeds the NAAQS for O_3 (0.70 ppm) and the Clark County number of exceedances of the PM_{10} NAAQS exceeds the standard (EPA 2024a). Therefore, shoreline exposure that has the potential to increase particulate matter could further exacerbate the current PM_{10} issue in Clark County.

TA 7.2.3 Issue 2: How would lake reservoir elevations and releases impact power generation and CO_2e emissions?

Issue 2 addresses how operational activities for the various alternatives affect reservoir elevations and therefore impact hydropower generation. When there is a reduction of hydropower, there would be a potential increase of CO_2e emissions due to more emissive alternative energy generation compensating for this reduction (Veselka et al. 2024). There will be a comparison of the four action alternatives and the No Action Alternative to the CCS Comparative Baseline. Power generation depends on the same factors as power capacity, but generation reflects the amount of power created over a certain period. The power generation is more dependent on plant operations through scheduled releases, as these releases, along with other natural factors like rainfall and water availability, determine how much water flows through the turbines over a given amount of time. These models simulate releases and lake reservoir elevations to calculate an estimated generation.

Energy capacity is the maximum possible electric output at a given time. Installed hydropower plant capacity is dependent on generator capacity and turbine efficiency, but the actual capacity is also dependent on the flow rate of water moving through the system. Therefore, the reservoir storage and lake elevation impact capacity for hydropower. Capacity for hydropower is dependent on the time of year as well as water availability differs between the summer and winter months. Lake elevation impacts the head, and a larger head leads to greater potential energy. The maximum capacity of hydropower will be the most instantaneous power generated in a second with the highest water flow possible through the turbines of a hydropower plant. The critical elevations for Lake Powell and Lake Mead are presented in tables in **TA 15**, Dams and Electrical Power Resources. At Lake Powell the minimum power pool is 3,490 feet and when water elevations go below this, Glen Canyon Dam is no longer able to produce hydropower. As described in **Chapter 1**, **Section 1.8.4.1**, this threshold is also important to protect critical infrastructure and water supply. At Lake Mead the minimum power pool is 950 feet and when water elevations go below this, Hoover Dam is no longer able to produce hydropower. This is typically measured in megawatts. This section will consider how the different alternatives impact the generation capacities of the hydropower plants at the Glen Canyon, Hoover, Davis, and Parker dams.

The box plots below report metric tons of CO_2e based on the 2025 resource mix emission factor on the left axis and the 2050 resource mix emission factor on the right axis, utilizing the MWh increase

or decrease for each alternative and flow category. Only the 2025 resource mix is discussed in detail, as the 2050 resource mix results would have lower metric tons of CO_2e as the emission factor includes more alternative energy resources.

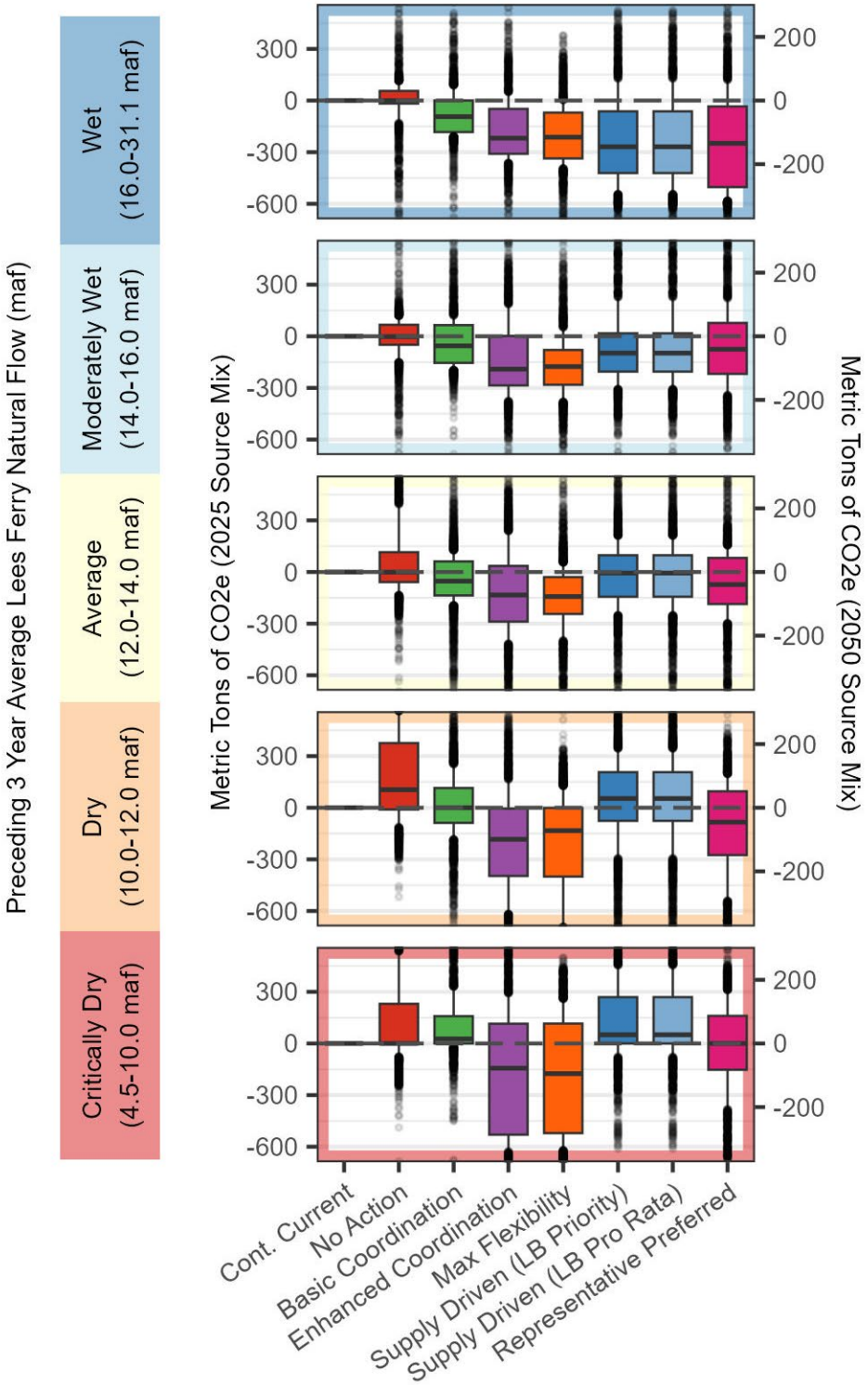
Figure TA 7-14 shows the change of CO_2e emissions due to a fluctuation of hydropower generation at Glen Canyon Dam, broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows.

A positive or negative CO_2e value indicates an increase or decrease in CO_2e compared to the CCS Comparative Baseline, respectively. In the Average Flow Category, the Glen Canyon Dam alternatives have varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 288-metric-ton decrease to a 115-metric-ton increase of CO_2e emissions. The No Action Alternative has a median close to zero, representing the smallest decrease relative to the CCS Comparative Baseline. The Enhanced Coordination (134 metric tons decrease of CO_2e) and Maximum Operational Flexibility (143 metric tons decrease of CO_2e) Alternatives have similar medians, resulting in the largest decrease in CO_2e emissions relative to the CCS Comparative Baseline. While the Maximum Operational Flexibility Alternative has an interquartile range similar to the other alternatives, the Enhanced Coordination Alternative has the largest interquartile range among all alternatives. The Average Flow Category 75th percentile values result in no more than a 115 metric ton increase in CO_2e emissions, which is equivalent to 23.3 gasoline-powered passenger vehicles driven for 1 year or 20.8 homes' electricity for 1 year.

In the Critically Dry Flow Category, the Glen Canyon Dam alternatives exhibit variations in both their medians and interquartile ranges. The No Action Alternative has a median value of zero CO_2e emissions relative to the CCS Comparative Baseline. The Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives show medians above zero, indicating an increase in CO_2e emissions relative to the CCS Comparative Baseline. The Enhanced Coordination and Maximum Operational Flexibility Alternatives both result in a decrease in CO_2e emissions, displaying medians below zero. The interquartile range for these two alternatives is the largest among all alternatives, with the middle 50 percent spanning from an approximate decrease of 530 to an increase of 115 metric tons of CO_2e. The Critically Dry Flow Category 75th percentile values result in no more than a 269 metric ton increase in CO_2e (Supply Driven Alternative), which is equivalent to 65.5 gasoline-powered passenger vehicles driven for 1 year or 58.6 homes' electricity for 1 year.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Glen Canyon Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about an 84-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 275-metric-ton decrease to a 96-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Glen Canyon Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions results in a zero-metric-ton increase or decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 153-metric-ton decrease to a 160-metric-ton increase of CO_2e emissions.

Figure TA 7-14
Change of CO2e Emissions Due to a Fluctuation of Hydropower Generation at Glen Canyon



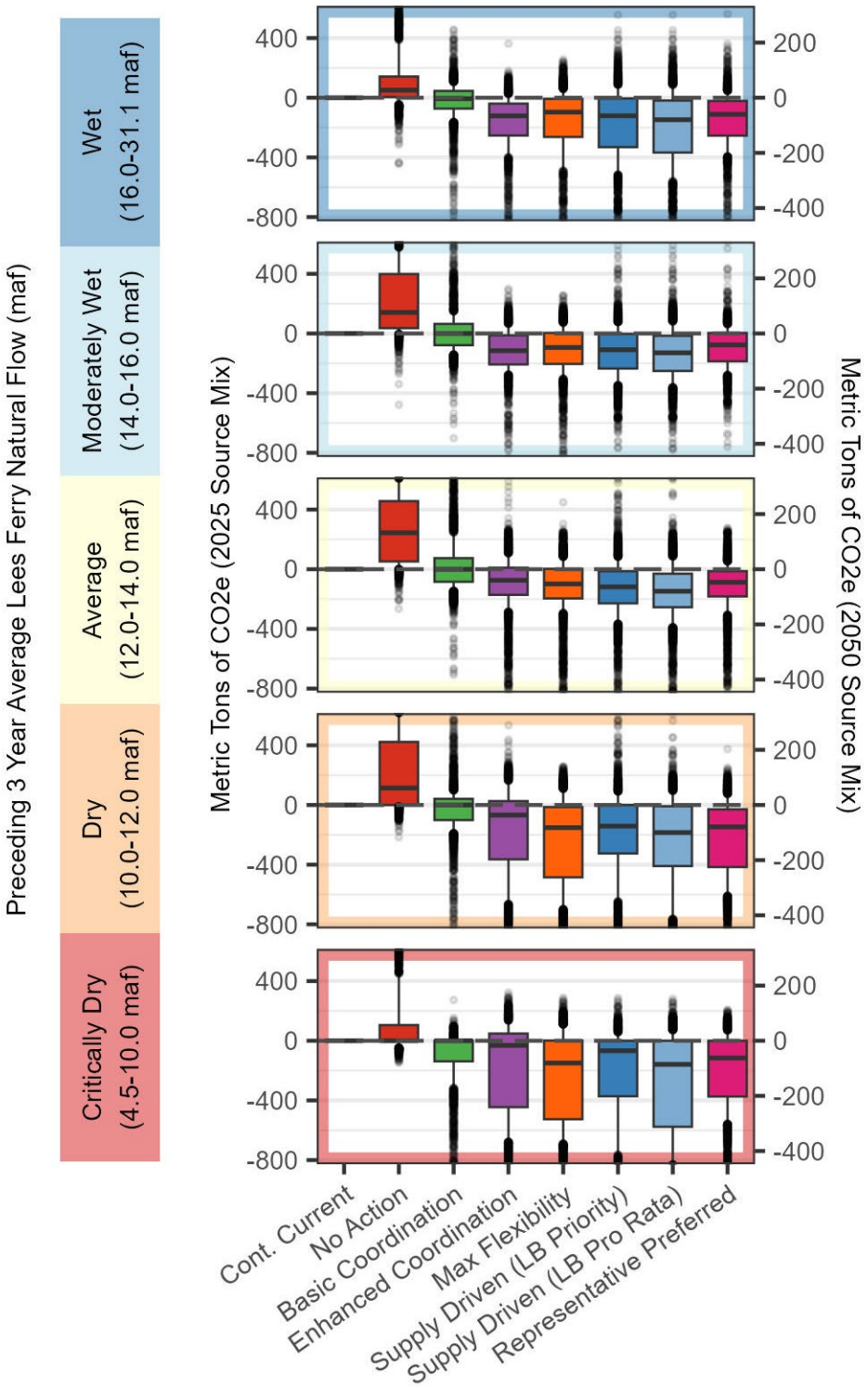
The median change in CO_2e emissions resulting from a loss of hydropower generation at Glen Canyon Dam generally shifts upward as hydrologic conditions move from Wet (16.0–31.1 maf) to Critically Dry (4.46–10.0 maf) Flow conditions; however, the magnitude of this shift varies among alternatives. The Enhanced Coordination and Maximum Operational Flexibility Alternatives exhibit relatively small changes in median CO_2e emissions across flow conditions, whereas the Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches) shows a more substantial increases in median emissions under drier conditions.

Figure TA 7-15 shows the change of CO_2e emissions due to a fluctuation of hydropower generation at Hoover Dam, broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows. The Hoover Dam power plant has 17 commercial generators with a maximum combined capacity of 2,074 megawatts. The power plant requires a minimum Lake Mead elevation of 950 feet to produce power. At minimum power pool, the power plant has an estimated capacity of 117 megawatts. At Lake Mead elevation of 1,035 feet, Hoover Dam's generating capacity is drastically reduced from 1,274 to 382 megawatts.

A positive or negative CO_2e value indicates an increase or decrease in CO_2e compared to the CCS Comparative Baseline, respectively. In the Average Flow Category, the Hoover Dam alternatives have varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 255-metric-ton decrease to a 456-metric-ton increase in CO_2e emissions. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives have medians showing a decrease in metric tons of CO_2e emissions. The No Action Alternative has a median showing an increase in metric tons of CO_2e emissions, and the Basic Coordination Alternative shows a median near zero metric tons of CO_2e emissions. The No Action Alternative has the highest median, with a 244-metric-ton increase in CO_2e emissions, and the largest interquartile range, with the 25th percentile at 52 metric tons and the 75th percentile at 456 metric tons of CO_2e. The Average Flow Category 75th percentile values result in no more than a 456 metric ton increase in CO_2e (No Action Alternative), which is equivalent to 90.3 gasoline-powered passenger vehicles driven for 1 year or 80.6 homes' electricity for 1 year.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Hoover Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 146-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 416-metric-ton decrease to a 75-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Hoover Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 115-metric-ton decrease of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 374-metric-ton decrease to a zero-metric-ton increase or decrease of CO_2e emissions.

Figure TA 7-15
Change of CO2e Emissions Due to a Fluctuation of Hydropower Generation at Hoover Dam



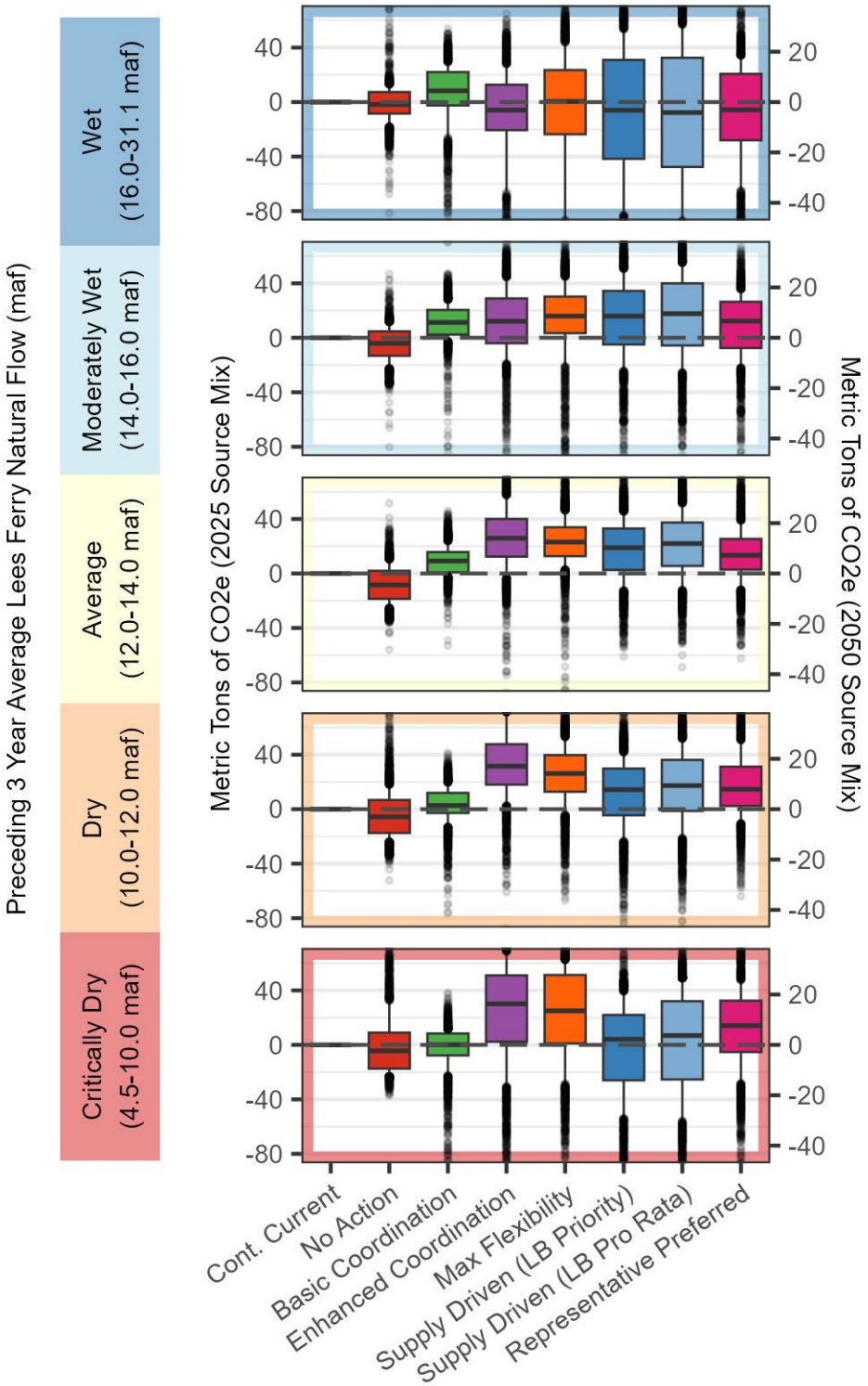
In the Critically Dry Flow Category, Hoover Dam alternatives exhibit variations in both their medians and interquartile ranges. The medians for the No Action and Basic Coordination Alternatives display no change in CO_2e emissions relative to the CCS Comparative Baseline. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives all have medians showing a decrease in metric tons of CO_2e emissions, with Supply Driven (LB Pro Rata) showing the largest decrease at 158 metric tons of CO_2e. The 25th to 75th percentiles across all alternatives span from a decrease of 577 metric tons to an increase of 105 metric tons of CO_2e emissions. The No Action Alternative has the smallest interquartile range, while the Supply Driven (LB Pro Rata) Alternative has the largest. The Critically Dry Flow Category 75th percentile values result in no more than a 105 metric ton increase in CO_2e (No Action Alternative), which is equivalent to 38.5 gasoline-powered passenger vehicles driven for 1 year or 34.4 homes' electricity for 1 year.

Figure TA 7-16 shows the change of CO_2e emissions due to a fluctuation of hydropower generation at Davis Dam, broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows.

A positive or negative CO_2e value indicates an increase or decrease in CO_2e compared to the CCS Comparative Baseline, respectively. In the Average Flow Category, the Davis Dam alternatives exhibit varying distributions of CO2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 19-metric-ton decrease to a 40-metric-ton increase in CO_2e emissions. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives display similar medians ranging from 19 to 26 metric tons of CO_2e increase. The Representative Preferred Alternative and Basic Coordination Alternative medians are similar at around 10 metric tons of CO_2e increase, while the No Action Alternative has an 8 metric ton decrease in CO_2e emissions. The No Action Alternative is the only alternative with both a median and 25th percentile below zero. All other alternatives have medians and 25th to 75th percentiles that result in an increase in CO_2e, with the Basic Coordination Alternative having the smallest interquartile range. The Average Flow Category 75th percentile values result in no more than a 40-metric-ton increase in CO_2e (Enhanced Coordination Alternative), which is equivalent to 10 gasoline-powered passenger vehicles driven for 1 year or 9 homes' electricity for 1 year.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the Davis Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 15-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 2-metric-ton increase to a 31-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Davis Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 14-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 5-metric-ton decrease to a 32-metric-ton increase of CO_2e emissions.

Figure TA 7-16
Change of CO2e Emissions Due to a Fluctuation of Hydropower Generation at Davis Dam



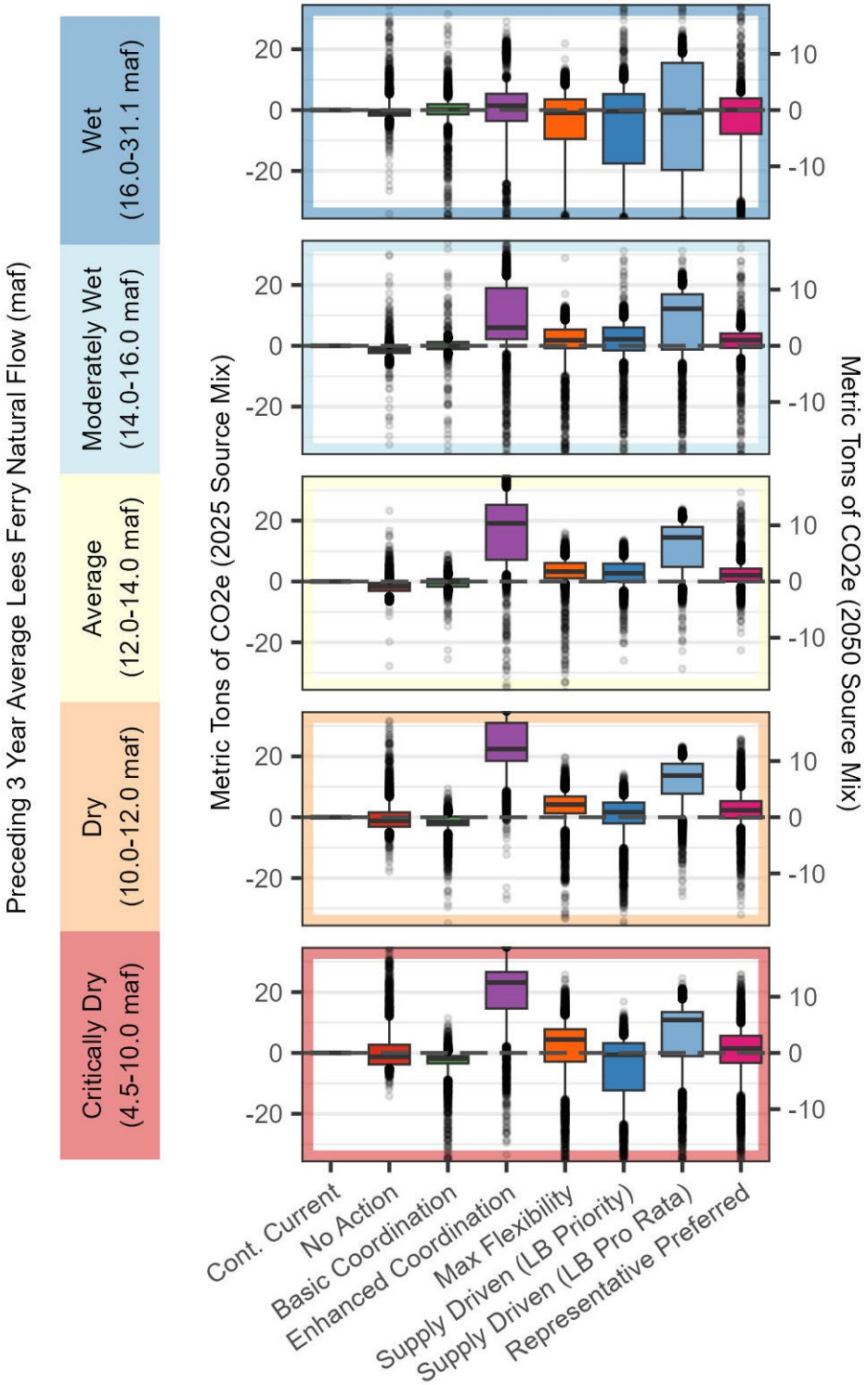
In the Critically Dry Flow Category, Davis Dam alternatives exhibit variations in both their medians and interquartile ranges. The median for the Basic Coordination Alternative displays very little change in CO_2e emissions, while the No Action Alternative shows a 4 metric ton decrease of CO_2e emissions relative to the CCS Comparative Baseline. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives all have medians showing an increase in CO_2e emissions, ranging from 4 to 30 metric tons. The 25th to 75th percentiles across all alternatives span from a decrease of 26 metric tons of CO_2e to an increase of 51 metric tons of CO_2e emissions. The Basic Coordination Alternative has the smallest interquartile range, while the Maximum Operational Flexibility Alternative has the largest. The Critically Dry Flow Category 75th percentile values result in no more than a 51-metric-ton increase in CO_2e (Enhanced Coordination Alternative), which is equivalent to 11 gasoline-powered passenger vehicles driven for 1 year or 9.8 homes' electricity for 1 year.

Figure TA 7-17 shows the change of CO_2e emissions due to a fluctuation of hydropower generation at Parker Dam, broken out by hydrologic conditions and categorized by the preceding three-year average Lees Ferry natural flows.

A positive or negative CO_2e value indicates an increase or decrease in CO_2e compared to the CCS Comparative Baseline, respectively. In the Average Flow Category, Parker Dam alternatives exhibit varying distributions of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 3-metric-ton decrease to a 25-metric-ton increase in CO_2e. Only the No Action and Basic Coordination Alternatives have medians that result in a decrease in CO_2e emissions; though, both are near a zero metric-ton change in CO_2e. The Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives have similar medians, ranging from near zero to a 5-metric-ton CO_2e increase. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have the highest medians, exceeding an increase of 14 metric tons of CO_2e emissions. The Enhanced Coordination Alternative has the largest interquartile range, while the Basic Coordination Alternative has the smallest range. The Average Flow Category 75th percentile values result in no more than a 25-metric-ton increase in CO_2e (Enhanced Coordination Alternative), which is equivalent to 5.4 gasoline-powered passenger vehicles driven for 1 year or 4.8 homes' electricity for 1 year.

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category : For the Parker Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 2-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a zero-metric-ton increase to a 5-metric-ton increase of CO_2e emissions. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the Parker Dam CO_2e emissions resulting from a loss of hydropower generation, the median CO_2e emissions is about a 1-metric-ton increase of CO_2e emissions, with the 25th to 75th percentiles across all alternatives spanning from a 3-metric-ton decrease to a 6-metric-ton increase of CO_2e emissions.

Figure TA 7-17
Change of CO2e Emissions Due to a Fluctuation of Hydropower Generation at Parker Dam



In the Critically Dry Flow Category, Parker Dam alternatives exhibit variations in both their medians and interquartile ranges. The medians for No Action, Basic Coordination, Supply Driven (LB Priority), and Representative Preferred Alternatives are similar, displaying a decrease in CO_2e emissions ranging from 2 to nearly zero metric tons. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (LB Pro Rata) Alternatives all have medians showing an increase in metric tons of CO_2e emissions, with the Enhanced Coordination Alternative showing the largest increase at 23 metric tons of CO_2e. The 25th to 75th percentiles across all alternatives span from a decrease of 12 metric tons of CO_2e to an increase of 27 metric tons of CO_2e. The Basic Coordination Alternative has the smallest interquartile range, while the Supply Driven Alternative (LB Priority) has the largest. The Critically Dry Flow Category 75th percentile values result in no more than a 27-metric-ton increase in CO_2e (Enhanced Coordination Alternative), which is equivalent to 6.1 gasoline-powered passenger vehicles driven for 1 year or 5.4 homes' electricity for 1 year.

TA 7.2.4 Issue 3: How would climate trends affect lake reservoir elevations?

Climate trends affect lake reservoir elevations in several interrelated ways, driven largely by changes in temperature, precipitation patterns, and hydrological cycles. Climate trends typically result in more variability and extremes in lake reservoir elevations—lower lows during droughts, higher highs during storm events, and greater management complexity overall.

Reduced Snowpack and Earlier Snowmelt

In many regions, especially mountainous areas, snowpack acts as a natural reservoir, slowly releasing water into rivers and lakes as it melts. Climate trends may cause warmer temperatures, which can result in less snow accumulation and earlier snowmelt, shifting the timing of runoff. Reservoirs may fill earlier in the season, but levels drop later in summer when demand (especially for irrigation and cooling) is highest.

Increased Evaporation

Potentially higher temperatures increase evaporation rates from both lake surfaces and surrounding land. As a result, greater water loss from reservoirs, especially in arid and semi-arid regions, leads to lower water levels.

Changes in Precipitation Patterns

Climate trends show potential disruption of rainfall patterns with some areas experiencing more intense storms, while others face prolonged droughts. The intense rainstorms may cause runoff that does not efficiently recharge reservoirs, and the droughts reduce inflow from rivers and streams, lowering reservoir levels over time.

Increased Water Demand

Hotter temperatures and more extreme weather increase demand for agricultural irrigation, municipal use, and power generation (cooling). Reservoir drawdown increases, reducing water levels faster, especially in peak summer months.

Decreased Hydropower

As discussed in Issue 2, hydropower may be affected by climate trends. Any reduction in hydropower would require other power generation sources to increase to compensate. The regional power mix can be analyzed to determine the region's potential capacity to replace hydropower with other alternative energy sources. The eGrid is a comprehensive inventory of environmental attributes of electric power systems. The eGrid is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. It provides the generation resource mix for the North American Electric Reliability Corporation regions.

The project is located in the Western Electricity Coordinating Council North American Electric Reliability Corporation region. The latest version of eGrid (eGrid 2023) was released in January 2025 with data from 2023 (EPA 2025f). **Table TA 7-15** shows that renewables such as hydropower, biomass, wind, solar, and geothermal are 42.8 percent of the Western Electricity Coordinating Council resource mix compared to nonrenewable resources, such as coal, oil, nuclear, and gas, totaling 57.3 percent. If the 19.8 percent hydropower is reduced, both renewable and nonrenewable resources would compensate. However, as discussed, a recent Argonne National Laboratory study shows that when there is a reduction in hydropower at Glen Canyon Powerplant, the replacement is generated from mostly natural gas–fired generation (gas combined cycle) and gas combustion turbine, with a small portion also coming from coal-fired generation for 2024 through 2027 (Veselka et al. 2024).

In addition, as climate trends are further observed and monitored, Reclamation has opportunity to discuss any strategies to increase management flexibility, enhance climate adaptation planning and improve infrastructure resilience.

Table TA 7-15
eGrid 2023 WRCC Resources Mix Percentages

Resource	Generation Percentage
Coal	14.0%
Oil	0.1%
Gas	35.5%
Nuclear	7.7%
Hydropower	19.8%
Biomass	1.1%
Wind	10.2%
Solar	9.5%
Geothermal	2.2%

Sources: EPA 2025f

TA 7.2.5 Summary of Comparison of Alternatives

Potential impacts on air quality resources for the No Action Alternative, the four action alternatives, and the CCS Comparative Baseline vary depending on the shoreline exposure area and the reduction of hydropower for each alternative.

Issue 1: How would changing flow characteristics affect the potential exposed shoreline, fallowed agricultural lands and fugitive dust?

For the Lake Powell WY maximum exposed shoreline area Average Flow Category, the alternatives all have similar medians and small variabilities, except the Enhanced Coordination and Maximum Operational Flexibility Alternatives, which have the lowest median km^2 of exposed shoreline and the smallest variability. For the Lake Mead WY maximum exposed shoreline area Average Flow Category, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the lowest median shoreline exposure area. The CCS Comparative Baseline and No Action Alternative perform the worst and have the smallest variability. The Basic Coordination Alternative performs in the middle. These results are within the range analyzed across the other alternatives from the Final Environmental Impact Statement.

For the full modeling period, the Lake Mead shoreline area robustness figure shows that the No Action Alternative performs the worst, with only 35 percent of the futures below 500 km^2 (123,553 acres) of shoreline area. The CCS Comparative Baseline performs slightly better at 50 percent, then the Basic Coordination Alternative at 61 percent, and then the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) at 72 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 80 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area. These same trends were seen for the 2027–2039, 2040–2049, and 2050–2060 modeling periods with higher percentages. For the 2027–2039 modeling period and 2040–2049 modeling period, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 88 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area.

The Lake Mead vulnerability plot shows that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions and less than 50 percent of the Drying with Variability traces include a driest 10-year average Lees Ferry annual flow this dry or drier. The Basic Coordination Alternative is similar to the median of the Drying with Variability ensemble, and the CCS Comparative Baseline and No Action Alternative are the most vulnerable at 10-year average flows of 10.5 maf and 11.4 maf, respectively.

For the full modeling period, the Lake Powell shoreline area robustness figure shows that the No Action Alternative performs the worst, with only 16 percent of the futures below 500 km^2 (123,553 acres) of shoreline area. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs slightly better at 23 percent, then the Basic Coordination Alternative at 27 percent, and then CCS Comparative Baseline at 33 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 80 percent of the futures below 500 km^2 (123,553 acres) of shoreline area. Similar trends were seen for the 2027–2039, though

with higher percentages. The 2040–2049 and 2050–2060 modeling periods show that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the worst, then the No Action Alternative. For the 2027–2039, 2040–2049, and 2050–2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 87 percent or more of the futures below 500 km^2 (123,553 acres) of shoreline area.

The Lake Powell vulnerability plot shows that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are least vulnerable, as fewer than 25 percent of the Drying with Variability traces include a driest 10-year average Lees Ferry annual flow this dry or drier. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable under flow conditions associated with more than 75 percent of the Drying with Variability traces and are therefore the most vulnerable.

For the Lake Powell WY maximum shoreline dust emissions Average Flow Category, several alternatives have similar medians, though Enhanced Coordination and Maximum Operational Flexibility Alternatives have the lowest median shoreline dust emissions and the smallest variability.

For the Lake Mead WY maximum shoreline dust emissions Average Flow Category, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the least shoreline dust emissions. The CCS Comparative Baseline and No Action Alternative perform the worst, with the highest shoreline dust emissions. The Basic Coordination Alternative performs in the middle.

For the full modeling period, the Lake Mead shoreline dust emissions robustness figure shows that the No Action Alternative performs the worst, with only 22 percent of the futures below 500 million kg (1,102 million pounds) of $PM_{2.5}$. The CCS Comparative Baseline performs slightly better at 40 percent, then the Basic Coordination Alternative at 52 percent, and then the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at 64 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 76 percent and 69 percent, respectively, of the futures below 500 million kg (1,102 million pounds) of $PM_{2.5}$. These same trends were seen for the 2027–2039, 2040–2049, and 2050–2060 modeling periods with higher percentages, and the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 79 percent or more of the futures below 500 million kg (1,102 million pounds) of $PM_{2.5}$.

The Lake Mead vulnerability plot shows that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are least vulnerable, with vulnerability thresholds corresponding to conditions associated with roughly 25 to 50 percent of the Drying with Variability traces. The CCS Comparative Baseline and Basic Coordination Alternative are vulnerable to conditions associated with roughly 50 to 75 percent of the Drying with Variability traces. The No Action Alternative has a vulnerability threshold of 11.7 maf, which is similar to the driest observed 10-year period of 11.8 maf.

For the full modeling period, the Lake Powell shoreline dust emissions robustness figure shows that the No Action Alternative performs the worst, with only 10 percent of the futures below 450 million kg (992 million pounds) of $PM_{2.5}$. The Basic Coordination Alternative performs slightly better at 21

percent, then the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at 22 percent, and then CCS Comparative Baseline at 28 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with 78 percent or more of the futures below 450 million kg (992 million pounds) of $PM_{2.5}$. These same trends were seen for the 2027–2039 with higher percentages. The 2040–2049 and 2050–2060 modeling periods show that the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform the worst, then the No Action Alternative. For the 2027–2039, 2040–2049, and 2050–2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have 84 percent or more of the futures below 450 million kg (992 million pounds) of $PM_{2.5}$.

The Lake Powell vulnerability plot shows that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to conditions associated with less than 25 percent of the Drying with Variability traces. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have vulnerability thresholds corresponding to conditions associated with 75 to 100 percent of the Drying with Variability traces and are therefore the most vulnerable alternatives. The No Action Alternative has a vulnerability threshold of 12.2 maf, which is similar to the recently observed 10-year flow of 12.1 maf.

Issue 2: How would lake reservoir elevations and releases impact power generation and CO_2e emissions?

For the Average Flow Category, both Glen Canyon Dam and Hoover Dam show that the Enhanced Coordination and Maximum Operational Flexibility Alternatives have median decreases in CO_2e emissions, with these alternatives having the largest median decrease at Glen Canyon Dam. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) also displays a median decrease in CO_2e emissions, with the LB Pro Rata approach showing the largest median decrease at Hoover Dam. The No Action Alternative displays very little change at Glen Canyon Dam but the largest median increase in CO_2e emissions at Hoover Dam. The Basic Coordination Alternative generally results in smaller median CO_2e emission changes that remain near zero. The Representative Preferred Alternative for both Hoover Dam and Glen Canyon Dam generally result in similar median CO_2e emissions decreases.

For the Average Flow Category, Davis Dam and Parker Dam exhibit similar patterns. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives show median increases in CO_2e emissions and generally the widest interquartile ranges. The No Action, Basic Coordination, and Representative Preferred Alternatives display the smallest median changes in CO_2e emissions, with the No Action Alternative being the only alternative to have a negative median change at both dams.

Issue 3: How would climate trends affect lake reservoir elevations?

Climate trends affects lake reservoir elevations in several interrelated ways, driven largely by changes in temperature, precipitation patterns, and hydrological cycles. Climate trends typically result in more variability and extremes in lake reservoir elevations, which may not be captured specifically in the modeling, but the five flow condition categories help to visualize the different potential states of the system throughout the 34-year period of analysis. Dry flow conditions could represent the lower

lows present during droughts and the wet flow conditions could represent the higher highs during storm events. General discussion of the effects of climate trends on lake reservoirs is discussed but due to uncertainty these effects cannot be determined for each specific alternative. In addition, **TA 3**, Hydrologic Resources, details the lake reservoir elevations for flow categories and alternatives.

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Technical Appendix 8

Biological Resources – Fish and Other Aquatic Species

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Attachment

TA 8 Attachment 1. Fish Species Life Histories

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
°C	degrees Celsius
°F	degrees Fahrenheit
2024 LTEMP Final SEIS	Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement
AZGFD	Arizona Game and Fish Department
BLM	Bureau of Land Management
BO	biological opinion
CCS	Continued Current Strategy
CI	confidence interval
CRSS	Colorado River Simulation System
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
ESA	Endangered Species Act
FWS	United States Fish and Wildlife Service
HFE	high-flow experiment
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Lower Basin	Lower Colorado River Basin
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
mg/L	milligrams per liter
mm	millimeter

NDOW	Nevada Department of Wildlife
NPS	National Park Service
NRA	National Recreation Area
PIT	Passive Integrated Transponder
Reclamation	Bureau of Reclamation
RM	river mile
SIB	Southerly International Boundary
U.S	United States
USGS	U.S. Geological Survey

TA 8. Biological Resources – Fish and Other Aquatic Species

TA 8.1 Affected Environment

The affected environment includes a diverse range of aquatic organisms, including foundational elements of the food web that support native and nonnative fish populations. Native fish species analyzed in this section are special status species, including federally threatened and endangered species, range-wide conservation species, Bureau of Land Management sensitive species, and Lower Colorado River Multi-Species Conservation Program (LCR MSCP) covered species. Nonnative fish species analyzed in this section include cold-water and warmwater species (see **TA 8 Attachment 1** for detailed life histories and distributions), including state-regulated sportfish. By affecting areas within the channel, along the shorelines, in backwaters, and at the mouths of tributaries, variations in river flow can impact these aquatic organisms and their habitats.

TA 8.1.1 Aquatic Food Base

The basic components of the aquatic food base are invertebrates, algae, rooted plants, and organic matter (Gloss et al. 2005). Although most of this food base is produced within the aquatic system, terrestrial inputs of organic matter and invertebrates also contribute. In turn, in-stream production of algae and invertebrates supports terrestrial consumers, such as grasshoppers and spiders, insectivorous birds and bats, reptiles, amphibians, mammals, and waterfowl. Indirect links include peregrine falcons, belted kingfishers, osprey, great blue herons, and bald eagles, which feed on fish or waterfowl that consume aquatic food base organisms (Bastow et al. 2002; Baxter et al. 2005; Sabo and Power 2002; Shannon et al. 2003; Stevens and Waring 1986; Yard et al. 2011). A description of the aquatic food base prior to and following Glen Canyon Dam's construction and operation can be found in the 2016 Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Final Environmental Impact Statement (EIS; Reclamation and NPS 2016) and was supplemented in the Glen Canyon Dam LTEMP Final Supplemental EIS (2024 LTEMP Final SEIS; Reclamation 2024). The following discussion includes invasive aquatic species that have affected or may affect food base organisms of the Colorado River ecosystem.

The aquatic food base's major groups include (1) periphyton (e.g., algae and cyanobacteria that live attached to rocks and other surfaces) and rooted aquatic plants, (2) plankton (very small plants [phytoplankton] and animals [zooplankton] that occur in the water column), and (3) macroinvertebrates (invertebrates that are visible to the naked eye). Large mainstream dams on the Colorado River have altered the river's physical, chemical, and biological characteristics by changing the flow, temperature, sediment, and salinity regimes (Cross et al. 2013). Nutrients and sediments have become trapped in reservoirs, such as Lake Powell, which has depleted the downstream reaches of important carbon sources for primary and secondary production and the foundational

sands and silts for the establishment of rooted vegetation that supports diverse riparian animal communities (Johnson and Carothers 1987). These changes have altered riverine food webs, reduced biodiversity, and often led to the extirpation of native species while facilitating the invasion of nonnative species (Miller 1961).

After Glen Canyon Dam was constructed, the combination of altered flows and temperatures, reduced organic inputs from areas upstream, decreased turbidity, and the altered thermal regime led to a shift in the Colorado River's aquatic food base downstream of the dam (Benenati et al. 2002; Blinn et al. 1995; Kennedy and Gloss 2005). In general, aquatic invertebrate diversity declined while density and biomass increased (Kennedy and Gloss 2005). The influence of Glen Canyon Dam, coupled with sediment inputs from tributary streams, resulted in a stepwise decrease in food base biomass in the Colorado River due to clear, cold hypolimnetic dam releases and downstream increases in turbidity from tributary sediment inputs. In the post-dam period, the 16-mile reach of Glen Canyon from the dam to Lees Ferry accounted for 69 percent of the algal and 50 percent of the macroinvertebrate mass collected throughout a 224-mile section of river downstream of the dam (Melis 2011). High sediment inputs from tributary streams downstream of the Paria River have resulted in an aquatic food base with lower biomass and species diversity. Suspended sediments increase turbidity, and deposited sediments alter substrate characteristics (Shannon et al. 1994; Shannon et al. 2001; Melis 2011). Thus, the aquatic food bases of the tailwater section (between the dam and the Paria River [Lees Ferry sub-reach]) differ from the rest of the mainstem (between the Paria River and Diamond Creek). In the clear tailwaters of the Lees Ferry sub-reach, aquatic productivity is driven primarily by photosynthetic production of algae, diatoms, and macroinvertebrates. The Colorado River downstream of the Paria River is seasonally influenced by tributary sediment and organic matter inputs, making the river more like pre-dam conditions, particularly as the distance from the dam increases (Rosi-Marshall et al. 2010) and water temperatures equilibrate with air temperature (i.e., warm in summer and cool in winter).

Most aquatic insects have complex life cycles with a terrestrial winged adult stage, while the egg, larval, and pupal stages are aquatic. Approximately 80 percent of adult aquatic insects (Kennedy et al. 2016) use river edge habitats for egg laying, whereby eggs are cemented onto rocks or vegetation along the river edge and just under the water surface. Brief desiccation of insect eggs (on a scale of hours), as is typical of eggs laid in the varial zone (water-shoreline interface that is wet and dry daily due to dam operations), leads to high mortality (Kennedy et al. 2016). This egg mortality effect is evident throughout the Grand Canyon, with aquatic insects more abundant where the timing of daily low flows coincides with peak egg-laying activity (i.e., late afternoon), because eggs laid in these locations are never subjected to desiccation-induced mortality. Additional evidence of this egg mortality effect is seen by comparing insect diversity downstream of dams throughout the western United States (U.S.), with insect diversity being strongly and negatively correlated to the degree of hydropower production (Kennedy et al. 2016). Thus, the varial zone downstream of hydropower dams, such as Glen Canyon, reduces the quality and availability of river edge habitats that aquatic insects use for their egg laying; this constrains both the diversity and abundance of aquatic insects present in these ecosystems and affects food sources for sensitive fish species. "Bug flows" were implemented as experimental releases from Glen Canyon Dam to increase the abundance (number of individuals) and diversity (number of species) of insects in the Grand Canyon by improving egg-

laying conditions (GCMRC 2022). These experiments were conducted in compliance with the 2016 LTEMP and are not associated with this EIS.

The Colorado River system is near large human population centers and is susceptible to the introduction of invasive aquatic species. Recreational boaters and anglers have inadvertently spread quagga mussels (*Dreissena bugensis*), New Zealand mud snails (*Potamopyrgus antipodarum*), and numerous aquatic plants into numerous locations of the Colorado River. Other nonnative and invasive species that have potentially detrimental effects on both the food base and fish communities have been established in the Colorado River. Nonnative and invasive species introductions, as related to the Colorado River food base, are discussed in detail in the 2024 LTEMP Final SEIS (Reclamation 2024).

TA 8.1.2 Fish Species

The Colorado River and its tributaries have supported a unique and highly indigenous native fish assemblage, as well as approximately 67 nonnative species introduced over the last century (Valdez and Muth 2005), primarily to sustain and support recreational sport fisheries. Because of a prolonged period of geologic isolation, particularly in the Upper Basin, the Colorado River had only 35 native fish species that were freshwater or euryhaline species (Miller 1955, 1958), including 14 in the Upper Basin (Valdez and Muth 2005). Of the 35 species native to the Colorado River system, 26 (74 percent) were endemic, or found in no other river basin on earth (Miller 1958). Of the 35 species, 3 are extinct, and 12 are listed as federally endangered or threatened (Bestgen et al. 2020; Minckley et al. 2003; Reclamation 2024). The fish species analyzed in this section are included in the 35 native species.

Native Fish Species

There are eight native fish species in the analysis area. Five of these species—the humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), Colorado pikeminnow (*Ptychocheilus lucius*), bonytail *(Gila elegans),* and desert pupfish (*Cyprinodon macularius*)—are federally listed, and the bluehead sucker (*Pantosteus discobolus*) and flannelmouth sucker (*Catostomus latipinnis*) are conservation species. The speckled dace (*Rhinichthys osculus*) is a sensitive species. The status and distributions of these native species in the analysis area are shown in **Table TA 8-1**. The roundtail chub (*Gila robusta*) was reported downstream of Lava Cliff Rapid (river mile [RM] 246) in the 1940s before the area was inundated by Lake Mead (Miller 1958), but it has not been subsequently observed in the mainstem downstream of Lake Powell. The species persists in the Little Colorado River in reaches outside the analysis area and is not included in the analyses.

Table TA 8-1
Native Fish of the Colorado River in the Analysis Area

Species	Listing Status[1]	Presence in Analysis Area[2] (river miles downstream from Lees Ferry)
Humpback chub (*Gila cypha*)	ESA-T, CH; AZ-SGCN	30-Mile Spring (29.8) to Pearce Ferry (280.7); Little Colorado River (61.8); translocated to Shinumo (109.2), Havasu (157.3), and Bright Angel (88.3) creeks. Some individuals occur downstream of Pearce Ferry and Pearce Ferry Rapid.

Species	Listing Status[1]	Presence in Analysis Area[2] (river miles downstream from Lees Ferry)
Razorback sucker (*Xyrauchen texanus*)	ESA-E, CH; AZ-SGCN	Bright Angel Creek (88.3) confluence to Pearce Ferry (280.7); few upstream of Lava Falls (179.7); much of Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu, as well as the much of the Lower Colorado River proper
Bonytail (*Gila elegans*)	ESA-E, CH; AZ-SGCN	Stocked in Lake Powell and Lower Colorado River reservoirs, the Lower Colorado River proper and its backwaters; recent bonytail larvae in Lake Powell indicate reproduction.
Colorado pikeminnow (*Ptychocheilus lucius*)	ESA-E, CH; AZ-SGCN	Colorado River and San Juan River inflows to Lake Powell as extensions of upstream populations
Desert pupfish (*Cyprinodon macularius*)	ESA-E, CH; AZ-SGCN	No natural, extant populations found in or along the Lower Colorado River. Isolated, constructed refuge ponds in the Bill Williams and Cibola National Wildlife Refuges
Flannelmouth sucker (*Catostomus latipinnis*)	NL; CSp; AZ-SGCN	Glen Canyon Dam (-15.8) to Pearce Ferry (280.7), including tributaries, inflow areas of Lake Powell and Lake Mead, as well as the reintroduced population downstream of Davis Dam
Bluehead sucker (*Pantosteus discobolus*)	NL; CSp; AZ-SGCN	Paria River (0.8) to Pearce Ferry (280.7), including tributaries
Speckled dace (R*hinichthys osculus*)	NL; AZ-SGCN	Paria River (0.8) downstream to Pearce Ferry (280.7), including tributaries

Sources: 56 *Federal Register* 54957; AZGFD 2001a, 2001b, 2002a, 2002b, 2003; Albrecht et al. 2014; Andersen et al. 2010; Bezzerides and Bestgen 2002; Coggins and Walters 2009; Francis et al. 2015; GCMRC 2014; Gloss and Coggins 2005; Makinster et al. 2011; Ptacek et al. 2005; Rees et al. 2005; Rinne and Magana 2002; Ward and Persons 2006; Woodbury 1959; FWS 2002; Valdez and Carothers 1998; Brockdorff 2022

[1]ESA = Endangered Species Act; E = endangered, T = threatened; CH = federally designated critical habitat in analysis area; AZ-SGCN = Arizona species of greatest conservation need; NL = not federally listed; CSp = included in the Range-wide Conservation Plan and Agreement and Strategy (UDWR 2006)

[2]Habitat and life-history information is presented in species-specific descriptions in this section.

Nonnative Fish Species

Generally, nonnative fish species in the Colorado River system pose risks to native fish species through competition for resources, predation, and habitat alteration. In limited cases, nonnative fish species in the Colorado River Basin can provide beneficial effects (i.e., fishing and providing forage for other sportfish [see **TA 14.1.11**, Sportfishing, in **TA 14**, Recreation]) depending on their location in the system and their recreational value. Reservoirs frequently support large populations of nonnative sportfish, and the tailwater of Glen Canyon Dam supports a high-value trout fishery. When nonnative species move outside of these sportfishing areas, they pose threats to native fish communities. In 2021 the National Park Service (NPS) Expanded Nonnative Aquatic Species Management Plan in Glen Canyon National Recreation Area (NRA) and Grand Canyon National Park (2018) was updated to better reflect the threat level of nonnative fish in Glen Canyon NRA and Grand Canyon National Park, below Glen Canyon Dam, based on their potential for predation, competition, or other adverse interactions with native and federally listed species, as well as to the

recreational rainbow trout (*Oncorhynchus mykiss*) fishery in the Lees Ferry sub-reach (NPS 2021). Four species were assigned a threat level of "(1) Very High," including smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), flathead catfish (*Pylodictis olivaris*), and brown trout (*Salmo trutta*). Five species were assigned a threat level of "(2) High," including rainbow trout (high in Grand Canyon National Park, low in Glen Canyon NRA), northern pike (*Esox lucius*), green sunfish (*Lepomis cyanellus*), striped bass (*Morone saxatilis*), white sucker (*Catostomus commersonii*), and burbot (*Lota lota*).

Nonnative, predatory species known to occur within the Upper and Lower Colorado River are black bullhead (*Ameiurus melas*), black crappie (*Pomoxis nigromaculatus*), white crappie (*Pomoxis annularis*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), striped bass, walleye, yellow bullhead (*Ameiurus natalis*), bluegill (*Lepomis macrochirus*), green sunfish, northern pike, and tiger muskie (*Esox lucius* × *Esox masquinongy*) (UDWR 2023).

TA 8.1.3 Reaches

Table TA 8-2 provides a complete list of the native and nonnative fish species within the analysis area, including the Colorado River from Lake Powell downstream to the Southerly International Boundary (SIB). The scientific name and conservation status of each species is presented in the table, and species present within each reach are shown in the table and described in more detail in the respective sections.

Lake Powell

For this analysis, the Lake Powell reach includes approximately 250 mi² covered by the lake (Root and Jones 2022) at its full elevation of 3,700 feet, including the inflows of two major rivers, the Colorado River and the San Juan River. Low levels of Lake Powell, starting with a receding reservoir in the year 2000, resulted in the creation of approximately 35 miles of additional riverine habitat for each of these rivers. As the lake recedes, the rivers carve through the existing sediment deposits, periodically deviating from their historical channels to carve new channels and in some cases, forming waterfalls that block the upstream movement of fish. On the San Juan River, there is an approximately 30-foot waterfall at Piute Farms acting as a major fish barrier (Cathcart et al. 2018; Pennock et al. 2024). The rapid incision rates in the Colorado River channel near the mouth of the Dirty Devil have eroded lake deposits, but the underlying bedrock has not yet been reached. If, upon further incision, the river encounters bedrock or another resistant layer, it is possible that rapids or waterfalls could form on the order of ~1 meter to ~10 meters (~3.3 to 33 feet; Arens 2023; Grams and Tusso 2023). At full pool, Lake Powell has a maximum depth of 568 feet. Lake Powell warms seasonally with the warmest surface temperatures of about 30 degrees Celsius (°C; 86 degrees Fahrenheit [°F]) in July and the coldest of about 5.5 °C (41.9 °F) in January. There is some ice formation along shorelines and sheltered bays in winter, but most of the lake remains ice-free. Lake Powell is a monomictic reservoir with strong thermal stratification through much of the spring, summer, and early fall, with the warmest surface layer (epilimnion) persisting from about May to October, a middle layer (metalimnion) where there is a steep transition between warm and colder water, and the lowest level (hypolimnion) with colder, typically hypoxic, conditions. Inflow from the Colorado River and the San Juan River generally flows into the hypolimnion but may mix with other layers depending on inflow density. At lower reservoir elevations, the metalimnion or epilimnion layers can extend down to the depth of the penstocks (3,470 feet elevation), resulting in warmer

Table TA 8-2
Native and nonnative fish species in the Colorado River from Lake Powell downstream to the SIB

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
Native Species									
bluehead sucker	*Pantosteus discobolus*	RWCS, BLM	Present in small numbers in reservoir and river inflows [1]	Abundant in tributaries and tributary mouths, present in mainstem [2]	Occasionally found at the Colorado River inflow area. [3, 4, 5]	Absent	Absent	Absent	Absent
bonytail	*Gila elegans*	FE, BLM, LCR MSCP	Juveniles (<111 mm total length) stocked by UDWR in 2022; rarely captured [6]	Two individuals captured in Lees Ferry sub-reach in 2023, likely pass through the dam from Lake Powell [6]	Only one record from Las Vegas Bay. [3, 4, 5]	Repatriation efforts; limited numbers. [3, 4]	Topock Gorge and upper Lake Havasu; annual stocking; occasionally found in backwaters downstream of Davis Dam. [3, 4]	Stocked; utilize backwater and riverine habitat. [3, 4]	Absent
Colorado pikeminnow	*Ptychocheilus lucius*	FE	Rare in the reservoir; numerous in Colorado River and San Juan River inflows drifting from upstream [7, 8]	Absent	Absent	Absent	Absent	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
desert pupfish	*Cyprinodon macularius*	FE	Absent	Absent	Absent	Absent	Present in isolated, constructed refuge ponds [20]	Present in isolated, constructed refuge ponds [20]	Absent
flannelmouth sucker	*Catostomus latipinnis*	RWCS, BLM, LCR MSCP	Present in small numbers in reservoir and river inflows [7]	Common in river and abundant in tributaries during spring spawning [3]	Found within the Colorado River Inflow area and occasionally near the Virgin River inflow area. [3, 4, 5, 9]	Absent	Introduced with numbers declining. [3, 4, 10]	Absent	Absent
humpback chub	*Gila cypha*	FT, LCR MSCP	Absent	Found as aggregations in river; abundant from Havasu Rapid to Pearce Ferry and in and around the Little Colorado River; introduced into Shinumo, Havasu, Bright Angel creeks [3]	Colorado River inflow area within full pool of Lake Mead. [3, 4, 5]	Absent	Absent	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
razorback sucker	*Xyrauchen texanus*	FE, BLM, LCR MSCP	Found in small numbers in reservoir; common in river inflows [7]	Rare upstream of Lava Falls Rapid; found in small numbers downstream of Lava Falls; translocated into the Little Colorado River and Havasu Creek by NPS/FWS [23]; move upstream from Lake Mead [3]	Sustained populations at the Colorado River inflow area, Las Vegas Bay, Echo Bay, and Overton Arm. Less abundant in Bonelli Bay. [3, 4, 5, 9]	Repatriated population; annual stocking; genetic refuge population. [3, 4, 11]	Stocked and found downstream of Davis Dam to Lake Havasu. [3, 4, 10]	Stocked; utilize backwater and riverine habitat. [3, 4]	Absent
speckled dace	*Rhinichthys osculus*	BLM	Found in small numbers along shoreline and canyons especially near inflow [12]	Numerous along shoreline, in mid-channel riffles, debris fans, tributaries and tributary mouths [3]	Numerous and common in Colorado River within the full pool of Lake Mead. [3, 4]	Absent	Absent	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
High-risk Nonnative Species									
brown trout	*Salmo trutta*	SRSF	Absent	found in increasing numbers in Lees Ferry with evidence of reproduction; found in tributaries including Bright Angel Creek and in the mainstem but abundance uncertain; considered very high-risk nonnative between GCD and Pearce Ferry[24,253]	Absent	Absent	Absent	Absent	Absent
flathead catfish	*Pylodictis olivaris*	SRSF	Absent	Absent	Absent	Absent	Common in Lake Havasu, and below Parker Dam. [22]	Present [13, 14, 15]	Present [14, 15]

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
green sunfish	*Lepomis cyanellus*	SRSF	Popular sportfish [7, 17]	Found in increasing numbers in Lees Ferry with evidence of reproduction; found downstream in tributaries and warm tributary mouths; considered dangerous invasive to native fish [3]	Common throughout. [4, 6, 8]	Common [5, 8]	Common [1, 7]	Common [9]	Presence is likely in unknown abundance. [3, 16]
rainbow trout	*Oncorhynchus mykiss*	SRSF	Absent	Popular sportfish in Lees Ferry sub-reach, high risk to native fish in downstream of Glen Canyon Dam to Pearce Ferry [2]	Occasionally found at the Colorado River inflow area. [3, 5]	Stocked and popular sportfish. [3, 18]	Stocked and popular sportfish. [3, 10]	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
smallmouth bass	*Micropterus dolomieu*	SRSF	Popular sportfish; Introduced by UDWR as 500 fry in 1982. [7, 17]	Found in increasing numbers in Lees Ferry with evidence of reproduction; found downstream but abundance uncertain; considered dangerous invasive to native fish [3]	Popular sportfish. [3, 5, 9, 18]	Popular sportfish. [3, 11, 18]	Popular sportfish. [3, 10, 16]	Popular sportfish. [13, 15]	Unknown
walleye	*Sander vitreus*	SRSF	Popular sportfish [7, 17]	Found in small numbers immediately downstream of the dam and increasing captures through Grand Canyon; considered dangerous invasive to native fish [3]	Occasionally found at the Colorado River inflow area. [9,18]	Absent	Absent	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
Nonnative, Regulated Sportfish									
black bullhead	*Ameiurus melas*	SRSF	Common along shorelines near rock structure and brush piles [7, 17]	Found in small numbers along shorelines and in warm tributaries and tributary mouths [3]	Common throughout. [3, 5, 9, 18]	Presumed rare. [3, 18]	Absent	Absent	Absent
black crappie	*Pomoxis nigromaculatus*	SRSF	Popular sportfish [7, 17]	Rare [3]	Popular sportfish. [3, 5, 9, 18]	Presumed rare. [3, 13]	Absent	Present in low abundance. [13, 14, 15]	Presence is likely in unknown abundance. [3, 16]
bluegill	*Lepomis macrochirus*	SRSF	Popular sportfish [7, 17]	Rare [3]	Popular sportfish and common throughout. [3, 5, 9, 18]	Popular sportfish; common. [3, 11, 18]	Common sportfish. [3, 10, 16]	Common [13, 14, 15]	Presence is likely in unknown abundance. [3, 16]
channel catfish	*Ictalurus punctatus*	SRSF	Popular sportfish [7, 17]	Found in small numbers along shorelines and in warm tributaries and tributary mouths [3]	Popular sportfish. [3, 5, 9, 18]	Popular sportfish. [3, 11, 18]	Common sportfish. [3, 10, 16]	Present in low abundance. [14, 15]	Presence is likely in unknown abundance. [3, 16]

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
fathead minnow	*Pimephales promelas*	FS	Abundant as an introduced forage species	Abundant primarily below the Little Colorado River as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species
gizzard shad	*Dorosoma cepedianum*	FS	Abundant	Rare, some entrainment through Glen Canyon Dam [23]	Abundant	Present	Present	Present	Present
golden shiner	*Notemigonus crysoleucas*	FS	Rare, sometimes used as baitfish by anglers	Rarely encountered [21]	Rare or absent	Absent	Absent	Absent	Absent
largemouth bass	*Micropterus salmoides*	SRSF	Popular sportfish [7, 17]	Found below Glen Canyon Dam and in small numbers throughout Grand Canyon 3, [23]in tributaries and warm tributary mouths [3]	Popular sportfish. [3, 5, 9, 18]	Popular sportfish. [3, 11, 18]	Common sportfish. [3, 10, 16]	Popular sportfish. [13, 14, 15]	Presence is likely in unknown abundance. [3, 16]
northern pike	*Esox lucius*	SRSF	Rare [7]	Absent	Absent	Absent	Absent	Absent	Absent

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
plains killifish	*Fundulus zebrinus*	FS	Abundant as an introduced forage and mosquito control species	Abundant primarily below the Little Colorado River as an introduced forage and mosquito control species	Abundant as an introduced forage and mosquito control species	Abundant as an introduced forage and mosquito control species	Abundant as an introduced forage and mosquito control species	Abundant as an introduced forage and mosquito control species	Abundant as an introduced forage and mosquito control species
red shiner	*Cyprinella lutrensis*	FS	Abundant as an introduced forage species	Abundant primarily below the Little Colorado River as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species	Abundant as an introduced forage species
striped bass	*Morone saxatilis*	SRSF	Popular sportfish [7, 17]	Found in small numbers that likely pass through the dam; upstream migration from Lake Mead 3	Popular sportfish. [3, 5, 9, 18]	Popular sportfish. [3, 11, 18]	Common sportfish. [3, 10, 16]	Present in low abundance. [14, 15]	Presence is likely in unknown abundance. [3, 16]
redear sunfish	*Lepomis microlophus*	SRSF	Absent	Absent	Absent	Absent	Common sportfish. [3, 10, 16]	Common. [13, 14, 15]	Presence is likely in unknown abundance. [3, 16]

Common Name	Scientific Name	Status[a]	Lake Powell	Glen Canyon Dam to Pearce Ferry	Lake Mead	Downstream of Hoover Dam to Lake Mohave	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to the SIB
					LCR MSCP Reach 1	LCR MSCP Reach 2	LCR MSCP Reach 3	LCR MSCP Reach 4, 5	LCR MSCP Reach 6, 7
threadfin shad	*Dorosoma petenense*	FS	Abundant as an introduced forage species for primarily striped bass	Generally absent, but found occasionally as escaped through Glen Canyon Dam	Present as an introduced forage species	Present	Present	Present	Unknown
white crappie	*Pomoxis annularis*	SRSF	Popular sportfish [7]	Rare	Absent	Absent	Absent	Absent	Absent
yellow bullhead	*Ameiurus natalis*	SRSF	Common along shorelines near rock structure and brush piles [7, 17]	Rare in the mainstem; few records in the Little Colorado River [19]	Less common than black bullhead. [3, 5]	Present in low relative abundance. [3, 11]	Present in Lake Havasu. [22]	Absent	Absent

[a]RWCS = Range-wide Conservation Species; FE = Federally endangered; FT = Federally threatened; SRSF = State-regulated sportfish; BLM = Bureau of Land Management special status species; LCR MSCP = Lower Colorado River Multi-Species Conservation Program covered species; FS = forage species; mm = millimeters.

[1]UDWR 2006, [2]Kegerries et al. 2020, [3]Pacey and Marsh 1998, [4]Bestgen et al. 2020, [5]Pennock et al. 2023, [6]FWS 2024a, [7]Mueller et al. 2001, [8]FWS 2022, [9]NDOW 2023, [10]NDOW 2020, [11]NDOW 2022, [12]Pennock et al. 2021, [13]Ham 2023a, [14]Ham 2023b, [15]Ramey and Ham 2024, [16]Mueller and Marsh 2002, [17]UDWR 2023, [18]Renner and Day 2022, [19]Marsh and Douglas 1997, [20] FWS 2012, [21]Valdez and Ryel 1995, [22]FWS 2018, [23]Emily Omana Smith, NPS, personal communication, 2025, [24]NPS 2018, [25]NPS 2021

release temperatures. Historically, the warmest release temperatures occurred in October and November as the reservoir cooled and mixed (Hueftle and Stevens 2001). In recent years, with lower reservoir elevations, the warmest months are early in the year, during September and October.

Preliminary analyses of long-term trends in limnological (aquatic ecosystem) data reveal directional changes in several parameters in Lake Powell over recent decades (Deemer et al. 2023). These initial data analyses suggest an increase in surface phytoplankton biovolume (algal biomass), which may be accompanied by changes in community composition and could have cascading effects on ecosystem function and water quality management. For example, cyanobacterial genera across all sites appear to have shifted considerably since the beginning of monitoring (1993–1997) compared to recent years (2017–2021). These community shifts could translate into changes in algal toxin formation and/or in the edibility of aquatic grazers. With the increasing frequency of harmful algal blooms, this could mean critical changes to Lake Powell's water quality for human use and aquatic life.

Altogether, there are six species of native fish analyzed in Lake Powell, including bonytail, bluehead sucker, Colorado pikeminnow, flannelmouth sucker, razorback sucker, and speckled dace (**Table TA 8-2**; Mueller et al. 2001). Bonytail were intentionally introduced into Lake Powell in 2022 by the Utah Division of Wildlife Resources (Smith 2022), and fish stocked upstream in the Upper Colorado and Green Rivers have moved into the reservoir (FWS 2024a). Colorado pikeminnow were found in the lake as it was reaching maximum pool elevation in 1980; these fish were likely migrating upstream to spawning sites in the Colorado River (Persons et al. 1982; Valdez et al. 1982). Today, Colorado pikeminnow in the lake are found mostly in the inflows of the Colorado and San Juan Rivers (Pennock et al. 2024; FWS 2022). Bluehead sucker and flannelmouth sucker are present in small numbers in the reservoir and river inflows, and razorback sucker are found in small numbers in the reservoir but are more common in the river inflows (Schleicher et al. 2024). Durst and Francis (2016) reported four razorback suckers moving from the San Juan Arm across Lake Powell and up the Colorado River, indicating movement across the Basin. The speckled dace is found in small numbers along the shoreline and canyons of the lake. Humpback chub were found in Lake Powell as the reservoir was filling and inundating the lower Cataract Canyon population (Valdez et al. 1982), but the species is not a lake species and has not persisted in the reservoir (Valdez 1990; Mueller et al. 2001).

There are at least 17 nonnative fish species in Lake Powell, including 12 state-regulated sportfish and 5 forage fish species (**Table TA 8-2**). Lake Powell is one of the more popular warmwater recreational lake fisheries in the southwestern U.S. The most common and popular sportfish caught by anglers are largemouth bass, black crappie, channel catfish, smallmouth bass, striped bass, walleye, bluegill, green sunfish, and bullheads (UDWR 2023).

Two species of nonnative bivalves have been discovered in Lake Powell: the Asian clam (*Corbicula fluminea*) and the quagga mussel. The Asian clam was first found in Lake Powell in 1991 (USGS 2024), and the quagga mussel was found in 2012 (Verde 2017). Both species are filter feeders that can alter the composition of plankton communities in lakes and reservoirs. Zebra mussels (*Dreissena polymorpha*), a close relative of the quagga mussel, have been implicated in promoting *Microcystis* in noneutrophic waters (Verde 2017). *Microcystis* is a genus of freshwater cyanobacteria that includes the harmful algal bloom-forming *Microcystis aeruginosa*. Many members of a *Microcystis* community can

produce neurotoxins and hepatotoxins, such as microcystin and cyanopeptolin, that pose a human health risk when ingested via untreated water.

Quagga mussels can disrupt the pelagic arm of the food web by interfering with the link between phytoplankton and herbivorous zooplankton (Verde 2017). This will likely have negative impacts on pelagic fish, such as striped bass and their main prey, threadfin shad (*Dorosoma petenense*), which rely on mid-water plankton. Quagga mussels may also boost benthic productivity in the littoral zone by diverting nutrients from the water column to the benthos following filtration and fecal output. This may have positive impacts on littoral fishes, such as largemouth bass, smallmouth bass, bluegill, and green sunfish.

Glen Canyon Dam to Pearce Ferry at Lake Mead

The Colorado River from Glen Canyon Dam to Pearce Ferry at Lake Mead spans approximately 295 miles through Arizona (USGS 2023). As the Colorado River exits Glen Canyon Dam, it flows through a series of rugged and steep canyons, including Glen Canyon (from the dam to the Paria River), Marble Canyon (from the Paria River to the Little Colorado River), and Grand Canyon (from the Little Colorado River to the Grand Wash Cliffs, RM 276). Pearce Ferry (RM 280) is 4 miles downstream of Grand Wash Cliffs. The river corridor in this reach is included in or borders Glen Canyon NRA, Grand Canyon National Park, the Hualapai Indian Reservation, the Navajo Nation, and Lake Mead NRA. This reach of the Colorado River has several major tributaries, including the Paria River, Little Colorado River, Clear Creek, Bright Angel Creek, Shinumo Creek, Tapeats Creek, Deer Creek, Kanab Creek, Havasu Creek, Diamond Creek, and Spencer Creek, along with numerous ephemeral tributaries.

Since the closure of Glen Canyon Dam in 1963, the Grand Canyon reach of the Colorado River has supported few native fish species due to extreme seasonal changes in flow and temperature, with substantial ecological shifts occurring in this reach (see **TA 8 Attachment 1** for details). Currently, the Grand Canyon supports a native-dominated fish community, with the highest abundance of humpback chub anywhere in its current range and flourishing populations of bluehead and flannelmouth sucker. The fish community is influenced by the river's complex flow patterns, variable water temperatures, and a diversity of habitats that reflect shoreline geology (Valdez and Ryel 1995). Today, five of the originally common species are known to persist in the Grand Canyon reach (**Table TA 8-2**). Native fish species analyzed in this reach include the endangered razorback sucker, the threatened humpback chub, as well as bluehead sucker, flannelmouth sucker, and speckled dace (NPS 2023a) (**Table TA 8-2**). Colorado pikeminnow, roundtail chub, and bonytail are extirpated from this reach. However, two bonytail have recently been detected in the reach and most likely moved from Lake Powell through Glen Canyon Dam. A proposal was also developed to evaluate the feasibility of stocking Colorado pikeminnow in the Grand Canyon, aiming to boost the recovery and resilience of this endangered species. An expert science panel reviewed current river conditions and concluded that the Grand Canyon now offers suitable habitat for adult and subadult pikeminnow, though limited juvenile survival may constrain recruitment. The panel recommended that experimental stocking, monitoring, and further research could help determine the viability of reintroduction in this changing environment (Dibble et al. 2023).

Nonnative fish species include rainbow trout, brown trout, largemouth bass, green sunfish, channel catfish, fathead minnow (*Pimephales promelas*), smallmouth bass, and other less common species (NPS 2023a; Shollenberger et al. 2025) (**Table TA 8-2**). Results from 2024 sampling (Shollenberger et al. 2025) indicate that smallmouth bass detections were highest between Glen Canyon Dam and the Paria River, with capture rates decreasing substantially downstream; however, the majority of sampling efforts were concentrated within the first 24 river miles downstream of Glen Canyon Dam. Electrofishing and netting efforts confirmed that smallmouth bass were rare in the lower reaches, with the most downstream detection at RM 16.4 in 2023 and 15.27 in 2024. The furthest downstream eDNA detection was at RM 37.5. Juvenile smallmouth bass were captured in 2022 and 2023 in the Lees Ferry sub-reach, which indicated reproduction (Reclamation 2025). In 2024, experimental low-temperature dam releases (cool mix flows) were initiated to prevent the establishment of a smallmouth bass population below Glen Canyon Dam (Reclamation 2024). No smallmouth bass nests were observed, no young-of-year were captured, and no evidence of recruitment was detected in 2024 following that experiment (Reclamation 2025). A significant increase in green sunfish captures was observed during the fall of 2023 compared to previous years, suggesting a strong recruitment and/or entrainment event. However, cooler conditions in 2024 likely prevented a similar influx of juvenile green sunfish, as suggested by lower capture rates in fall months. Green sunfish also exhibited reduced recruitment and/or entrainment and larger average sizes in 2024, suggesting minimal reproduction (Reclamation 2025). Entrainment modeling (Eppehimer et al. 2025) shows that the risk of smallmouth bass invasion below Glen Canyon Dam increases as Lake Powell elevation drops below 3,530 feet. It is especially hard to control entrainment below 3,510 feet with penstock releases. Keeping reservoir elevations above 3,570 feet can substantially reduce this risk. Lower lake levels also result in warmer downstream water, which favors nonnative fish that threaten native and Endangered Species Act (ESA)-listed species. If smallmouth bass establish downstream, removal would be difficult and costly (Eppehimer et al. 2025).

Flannelmouth sucker and bluehead sucker are "conservation species" that are included in a range-wide conservation agreement among six states (UDWR 2006). These species are found as self-sustaining populations and are locally common in the Colorado River from Glen Canyon Dam to Lake Mead (Kegerries et al. 2020). They are seasonally abundant during spring spawning runs into tributaries of the Colorado River, such as the Paria River, Havasu Creek, Kanab Creek, and Tapeats Creek. Both species have adjusted to changing riverine conditions following the construction of Glen Canyon Dam (Paukert and Rogers 2004; Valdez and Carothers 1998). Speckled dace are common to abundant within tributaries and near tributary inflows, as well as on rocky debris fans formed by debris flows from side canyons (Valdez and Ryel 1995; Kegerries et al. 2020). Flannelmouth sucker and bluehead sucker abundance typically increases with distance downstream of the Little Colorado River and is generally high near major tributary confluences, such as the Little Colorado River, Paria River, Kanab Creek, and Bright Angel Creek (Johnstone et al. 2003; Johnstone and Lauretta 2004; Rogowski et al. 2017).

The humpback chub population expanded in the western Grand Canyon in 2016. This is likely due to the warmer water and the lack of predators in the lower Grand Canyon (Dzul et al. 2023; Van Haverbeke et al. 2017; Rogowski et al. 2018; Kegerries et al. 2020; Rogers et al. 2023). As of 2022, a growing population of 50,000-84,000 adults between Havasu Rapids and Pearce Ferry was reported

(Van Haverbeke et al. 2023) and considered a single genetic population (Dzul et al. 2025). Since 2000, larvae and adult razorback suckers have also been found in the Colorado River inflow at the lower end of the Grand Canyon (and within Lake Mead proper), including sonic-tagged adults moving from one of the three Lake Mead populations (Kegerries et al. 2017a, 2017b). A confirmed spawning site was discovered in 2010 about 10 miles downstream of Pearce Ferry (Albrecht et al. 2010; Valdez et al. 2012; Albrecht et al. 2017). Although annual surveys for larval and small-bodied razorback suckers have been conducted in the Grand Canyon since 2014, no small-bodied fish have been detected, and larval fish have not been detected since 2019. The razorback sucker in the Grand Canyon is found primarily downstream of Lava Falls Rapid, with individuals rarely found upstream (Kegerries et al. 2020; Rogers et al. 2023). In 2024, 790 razorback suckers tagged with a passive integrated transponder (PIT) were stocked into the Little Colorado River; 70 were detected near the confluence with the Colorado River, and another 6 were recaptured in the Little Colorado River and the mainstream Colorado River (Ward and Wood 2025).

A total of 18 nonnative fish species have been reported between Glen Canyon Dam and Lake Mead from 1957 through 2023 (Valdez and Ryel 1995; Trammell et al. 2002; Fonken et al. 2023; Fennell et al. 2024). Native fish continue to dominate abundance, as total fish numbers, in the Grand Canyon fish community (Kegerries et al. 2020; Dzul et al. 2023). Small-bodied, nonnative fish like the fathead minnow, red shiner (*Cyprinella lutrensis*), and plains killifish *(Fundulus zebrinus*) are predominantly found downstream of the Little Colorado River confluence. Nonnative fish, including the golden shiner (*Notemigonus crysoleucas*), redside shiner, striped bass, and threadfin shad, infrequently occur in this reach. Evidence strongly indicates that this tributary is the primary source of these species in the Colorado River ecosystem (Johnstone et al. 2003), although additional sources include entrainment through Glen Canyon Dam, upstream movement from Lake Mead, and other tributaries (Rogowski et al. 2017).

The primary sportfish in the Colorado River between Glen Canyon Dam and Lake Mead inflow is the rainbow trout, which is maintained by the NPS and Arizona Game and Fish Department (AZGFD) in Lees Ferry as a recreational fishery. Natural reproduction of rainbow trout that move downstream in the Grand Canyon is dependent on cool water temperatures, access to tributaries for spawning, and continued availability of suitable mainstream habitat. These variables are directly affected by patterns and temperatures of water released from Lake Powell. McKinney and Speas (2001) found that *Gammarus*, chironomids, and Cladophora constituted about 90 percent of rainbow trout's food by volume during cold releases. In more recent warm releases, the diet of rainbow trout has shifted toward a greater variety of invertebrate and algal species, with midges and blackflies as major components (Cross et al. 2013).

Humpback chub rely on *Gammarus* and chironomids, but also consume larval simuliids (blackflies), which become more common downstream of the Paria River (Gloss et al. 2005). *Cladophora*, *Oscillatoria* spp., and terrestrial organic matter serve as key energy sources for aquatic invertebrates between Glen Canyon Dam and Lake Mead. *Cladophora* and *Oscillatoria* are also consumed by fish, largely because of the dense populations of lipid-rich diatoms (Gloss et al. 2005).

In 2012, the quagga mussel was found in Lake Powell (Verde 2017) and was identified in sampling locations between Glen Canyon Dam and Lees Ferry in November 2014. Mussels continue to be

found in the river downstream of the dam. Their distribution is patchy and highly influenced by fluctuating water levels and location-specific flow regimes (NPS 2023b). Kennedy (2007) reported that the risk of quagga mussels establishing within the Grand Canyon is generally low, except for the Lees Ferry tailwater reach, where the risk is high. Conditions within the Lees Ferry tailwater generally appear suitable for quagga mussel establishment, except for the high average water velocity. High suspended sediment, high ratios of suspended inorganic to organic material, and high-water velocities limit the quagga mussel's ability to establish at high densities within the Grand Canyon or its tributaries. Additionally, the rapids in the Grand Canyon contribute to high mortality rates for larval quagga mussels, limiting their ability to disperse and colonize downstream reaches.

The New Zealand mud snail has rapidly spread across the western U.S. and was first detected in the tailwaters downstream of Glen Canyon Dam in March 2002. Further investigations in the Grand Canyon revealed its presence more than 225 miles downstream from the dam (Cross et al. 2013), suggesting that it had been introduced several years prior. In suitable habitats, mud snail populations can exceed densities of 100,000 individuals per square meter. The species is known to cause ecological changes, including alterations in primary production and reductions in native invertebrate populations in the rivers it invades. New Zealand mud snail populations can increase quickly with suitable temperatures and riverine conditions and are of concern due to their potential impacts on native species, fisheries, and food web dynamics within the Grand Canyon (Cross et al. 2013; NPS 2015).

LCR MSCP Reaches

The LCR MSCP planning area comprises areas up to and including the full-pool elevations of Lakes Mead (1,229 feet), Mohave (647 feet), and Havasu (450 feet), and the historical floodplain of the Colorado River from Lake Mead to the SIB. Downstream of Hoover Dam to the SIB, mitigation and conservation measures to address potential impacts of reduced river flows have already been identified through recent ESA consultation processes. The 2023 biological assessment (LCR MSCP 2023) and the subsequent 2024 biological opinion (BO; FWS 2024b) prepared for the 2024 LTEMP Final SEIS (Reclamation 2024) evaluated the effects of reduced flows between approximately 1.574 and 2.083 maf and identified impacts on approximately 109 acres of backwater habitat and 41 acres of marsh habitat. As part of that consultation, Reclamation and FWS agreed to habitat creation to offset these impacts. The BO also established conservation measures to address potential ecological effects associated with low-flow conditions. These include actions to minimize impacts on covered species habitats at Topock Marsh while longer-term habitat measures are implemented, as well as additional short-term measures that would be implemented if flows were reduced between approximately 2.083 and 3 maf. These measures include minimizing the potential for stranding of native fishes due to reduced river stage, reducing impacts on entrained or stranded native fishes, minimizing effects on fish augmentation activities, and coordinating with mainstem national wildlife refuges to enhance and protect existing habitat areas.

For purposes of the Fish and Other Aquatic Species section of this document, we utilize the following reaches, as defined within LCR MSCP (2004):

Reach 1—from Separation Canyon (Grand Canyon RM 240) in the lower end of the Grand Canyon to Hoover Dam (Colorado RM 342.2), including Lake Mead up to full-pool elevation.

Reach 2—from Hoover Dam to Davis Dam (RM 276), including Lake Mohave up to full-pool elevation.

Reach 3—from Davis Dam (RM 276) to Parker Dam (RM 192.3), including Lake Havasu up to full-pool elevation.

Reach 4—from Parker Dam (RM 192.3) to Adobe Ruin and Bureau of Reclamation (Reclamation) Cibola Gage (RM 87.3) at the lower end of Reclamation's maintenance Cibola Division.

Reach 5—from Reclamation Cibola Gage (RM 87.3) to Imperial Dam (RM 49.2).

Reach 6—from Imperial Dam (RM 49.2) to the Northerly International Boundary (RM 23.1); and

Reach 7—portion of the Lower Colorado River from Northerly International Boundary (RM 23.1) to SIB (RM 0.0) within the U.S.

Note that due to the nature of the river downstream of LCR MSCP Reaches 4 and 5, particularly the scarcity of native and ESA-listed fishes and their survival, along with the current allocation of LCR MSCP fish sampling efforts primarily in Reaches 4–5 (J. Stolberg, LCR MSCP, personal communication; LCR MSCP 2024), we will present information from Reaches 4–5 as the lowest-most combined reach routinely sampled (from Parker Dam [RM 192.3] to Imperial Dam [RM 49.2]). We will not present data for Reaches 6–7 of the LCR MSCP.

LCR MSCP Reach 1- Lake Mead

Lake Mead has four major basins that tend to be separated by narrow connective canyons. In order from upstream to downstream, these include Gregg Basin, Virgin Basin, Boulder Canyon, and Boulder Basin, and can be classified as deep, subtropical, monomictic basins that become thermally stratified at times and typically for a brief period in July. The Muddy (Moapa) River and the Virgin River both discharge into the Overton Arm of the Virgin Basin, and Las Vegas Wash, which carries treated wastewater from the Las Vegas area, discharges into Las Vegas Bay of the Boulder Basin. These are considered the only perennial tributaries of Lake Mead (Baker et al. 1977).

The full-pool footprint of Lake Mead extends up to just upstream of Separation Canyon (RM 240 within the Grand Canyon) and encompasses the inflow area of the Colorado River into Lake Mead. For this document, given the current conditions at Pearce Ferry Rapid, we use it to separate the Grand Canyon from Lake Mead. We also note that Lake Mead, when full, encompasses various portions of the inflow areas of the Muddy River, the Virgin River, and Las Vegas Wash, all of which are perennial tributaries to the reservoir. We note that these inflow areas are highly dynamic, sometimes riverine and at other times lake-like, and provide diverse and important habitats for both native and nonnative fishes, resulting in a robust fish community at the Lake Mead inflow areas (Albrecht et al. 2017).

Lake Mead has a diverse fish community (**Table TA 8-2**) (Renner and Day 2022), as would be expected from the largest reservoir by volume within the U.S. (Rosen et al. 2012). Among all the ESA-listed fishes native to the Colorado River, the razorback sucker is the most prominent species in Lake Mead. This reservoir hosts a unique population of wild, naturally recruiting razorback

suckers. At the time of writing, Lake Mead is the only known location supporting a recruiting population of this species (Albrecht et al. 2010, 2020; Rogers et al. 2025a). Additionally, the NDOW, in collaboration with the LCR MSCP maintains the Lake Mead Fish Hatchery, which rears razorback sucker and bonytail. This fish production, when available, is used by the LCR MSCP for augmentation purposes throughout the LCR MSCP reaches (LCR MSCP 2024).

This document analyzes species **Table TA 8-2** provides a summary of fish species that are likely to be routinely present in the analysis area since Hoover Dam closed. Following the closure of Hoover Dam, NDOW stocked Lake Mead with largemouth bass and sunfishes (*Lepomis* spp.), establishing a popular bass fishery that began to decline by the 1940s. To improve sportfish conditions, threadfin shad were introduced in 1954 as a forage species.

The construction of upstream impoundments, including Lake Powell in 1963, altered flow regimes and water storage patterns, resulting in lower spring flows and higher winter flows, which negatively affected largemouth bass spawning and affected temperature and nutrient dynamics in Lake Mead (NDOW 2023). In response to the declining bass fishery, cold-water fish species such as rainbow trout, cutthroat trout (*Oncorhynchus clarkii)*, hybrid bowcutt trout (*Oncorhynchus mykiss* × *Oncorhynchus clarkii)*, silver salmon (*Oncorhynchus kisutch)*, and striped bass were introduced between 1969 and 1972, with striped bass establishing a self-sustaining population. Since surveys began in 1991, nonnative species have been regularly captured in Lake Mead, including striped bass, channel catfish, and common carp. NDOW documented the first walleye in 2001 and gizzard shad (*Dorosoma cepedianum*) in 2009. Red shiners continue to be routinely observed by researchers (Pennock et al. 2023; Rogers et al. 2025a). Smallmouth bass, first detected in 1999, have since become as abundant as largemouth bass despite not being officially stocked. Today, Lake Mead's sport fishery includes striped bass, largemouth bass, smallmouth bass, channel catfish, and a small population of black crappie (NDOW 2023).

The Muddy River and Virgin River inflows are not only used to varying degrees by razorback suckers but also have the potential to contain Virgin River chub (*Gila seminuda*), woundfin (*Plagopterus argentissimus*) (Virgin River only at present), flannelmouth sucker (Virgin River only at present), desert sucker (*Catostomus clarkii*) (Virgin River only at present), as well as speckled dace (Virgin River only at present), a likely extirpated subspecies of speckled dace, the Moapa speckled dace (*Rhinichthys osculus moapae*) (Muddy River), Moapa dace (*Moapa coriacea*) (Muddy River), populations of Moapa White River springfish (*Crenichthys baileyi moapae*) (Muddy River), and various headwater associated thermal spring associated endemic macroinvertebrates (Muddy River). Most of these species are documented in reaches higher up within these two river systems, as are Virgin spinedace (L*epidomeda mollispinis*), which is primarily a tributary-oriented species found within the tributaries to the mainstream Virgin River (e.g., Holden et al. 2005, Kegerries et al. 2022, and Handtke et al. 2024 for details on the Muddy River fish community; Albrecht et al. 2020 and Rogers et al. 2025a for details on the lower Virgin River fish community). In recent years, only Virgin River chub have been captured from within Lake Mead proper, a single specimen originating from within the Overton Arm (Rogers et al. 2025a).

Rogers et al. (2024 and previous annual reports) discuss Lake Mead razorback sucker history and trends since before dam construction. A study initiated in 1996 focused on long-term monitoring of

the Lake Mead razorback sucker population (Rogers et al. 2025a). This effort has continued through 2024, providing a consistent database and expanding sampling to new areas. By using data gathered from sonic-tagged fish in conjunction with long-term trammel-netting and larval-sampling data, information regarding primary spawning sites has been obtained for three long-term monitoring study areas (Las Vegas Bay, Echo Bay, and the Virgin River/Muddy River inflow area), and research sites (the Colorado River inflow area and Bonelli Bay) within Lake Mead. In addition to primary spawning site information, sonic-tagged fish have confirmed reservoir-wide and seasonal movement patterns within the long-term monitoring and research study areas.

Razorback suckers continue to spawn and recruit in Lake Mead (e.g., Rogers et al. 2025a). Multiple age classes of razorback suckers, including larvae, juveniles, and adults, are documented annually. The Lake Mead razorback sucker population consists of individuals ranging from 2 to 30+ years old, demonstrating relatively high growth rates indicative of a young, recruiting population. Population estimates have ranged from around 250 to nearly 1,400 razorback sucker in Lake Mead, with adult annual apparent survival rates of this largely wild population consistently documented at just under 80 percent (Rogers et al. 2025b)

It is important to note that since 1966, at least some razorback sucker recruitment has occurred nearly annually in Lake Mead. This suggests that lake elevations observed to date have not prevented this population from successfully recruiting. However, it is unclear whether a lower-end threshold exists, either defined bathymetrically by the availability of suitable spawning and recruitment habitat, or due to other recruitment-limiting factors at lake elevations lower than those observed to date.

Recently, both larvae and adult razorback suckers have been discovered utilizing both the lower Grand Canyon and the inflows to Lake Mead; razorback suckers have been documented to be spawning at least 100 river miles from Lake Mead consistently between 2014 and 2019 (Albrecht et al. 2014; Kegerries et al. 2017a, 2017b, 2020). Recent data from the Colorado River inflow (Rogers et al. 2023) suggests that Lake Mead razorback suckers move throughout not only Lake Mead, but also up into the Las Vegas Wash, and into the Grand Canyon when conditions allow. Major findings for this and previous studies to date include (1) multiple age classes of unmarked, wild razorback suckers (including juvenile fish) occupy the Colorado River inflow, and adults spawn there; (2) razorback suckers spawn within Grand Canyon or its associated tributaries; (3) sonic-tagged razorback sucker (stocked and wild) utilize both the Colorado River inflow and Grand Canyon; and (4) native fish dominate the fish community in Grand Canyon despite the presence of numerous nonnative fishes in Lake Mead and Lake Powell. Within the study period (2014–2023), as described in Rogers et al. (2023), razorback sucker use of the Grand Canyon and Colorado River inflow was documented. Overall, study results indicate an apparent interconnected, recruiting population of razorback suckers in Lake Mead that may demonstrate sufficient plasticity to allow for lentic and lotic habitat use in Lake Mead and the Grand Canyon.

In addition to razorback suckers, several other native fish occur in Lake Mead, including flannelmouth suckers, which were first captured in 2001, hybrid suckers (razorback x flannelmouth) documented in 2010, bluehead suckers in 2011, bonytail in 2020, and both humpback chub and Virgin River chub in 2021. Notably, humpback chub are relatively common upstream and

downstream of Pearce Ferry Rapid when riverine habitats are present (Hedden et al. 2022; Pennock et al. 2023; Rogers et al. 2024).

Dibble et al. (2021) describe geomorphic changes in the lower Grand Canyon resulting from recent declines in Lake Mead's elevation, which have extended the Colorado River by more than 62 river miles and shifted habitat conditions in favor of native fish species. When the elevation of Lake Mead dropped below 1,135 feet, the river downcut through the reservoir delta outside of its historic channel, forming Pearce Ferry Rapid, a bedrock ledge that acts as a barrier to the upstream movement of nonnative fishes from Lake Mead. This physical feature has significant implications for fish populations. If water management prioritizes Lake Powell storage, Pearce Ferry Rapid is likely to persist, thereby blocking or deterring the movement of nonnative fish upstream. Conversely, prioritizing Lake Mead storage could inundate the rapid and lower elevations of Lake Powell, which would warm the river, improving conditions for native fish but increasing the risk of nonnative fish invasions. An intermediate approach could maintain the current balance of barriers, deterrents, and thermal conditions, supporting native fish while limiting nonnative species (Dibble et al. 2021; Bruckerhoff et al. 2022).

Fish capture and movement data of razorback sucker, flannelmouth sucker, striped bass, and common carp collected or detected between 2012 and 2023 (Kegerries and Albrecht 2013a, 2013b; Albrecht et al. 2014; Kegerries et al. 2015; Rogowski et al. 2025), validate that Pearce Ferry Rapid likely functions as a barrier to fish movement, depending on lake elevation. Upstream movement was observed when mean monthly Lake Mead elevations exceeded approximately 1,090 feet. Rogowski et al. (2025) conclude that the rapid likely effectively restricts the upstream movement of nonnative fish species, thus protecting native habitats, although it may also impede the movement of some native species, potentially creating downstream population sinks. While some native species, such as humpback chub, appear to benefit from reduced predation and competition, the rapid also appears to limit connectivity for other native fish populations (e.g., razorback sucker and flannelmouth sucker). The barrier function of Pearce Ferry Rapid is dynamic and may shift over time due to geomorphic and environmental factors, such as changes in reservoir elevation, channel migration, or potential downcutting. Overall, the formation and persistence of Pearce Ferry Rapid demonstrate how a decline in reservoir elevation can create complex barriers with both positive and negative consequences for native fish conservation in the Grand Canyon (Dibble et al. 2021; Rogowski et al. 2025).

Quagga mussels were found in Lake Mead in January 2007, with the initial colonization likely occurring 3–4 years earlier, and are considered a biological threat to the lake (NPS 2023b). Significant impacts on water quality, lake biology, and infrastructure were expected based on experiences with zebra mussels in other parts of the country, but to date, no significant impacts on either water quality or lake biota have been published that can be directly attributed to quagga mussels (Renner and Day 2022; NPS 2023b). Another invasive bivalve in Lake Mead, the Asian clam, has also been observed during razorback sucker field monitoring and research (Rogers et al. 2025a), as have red swamp crayfish (*Procambarus clarkii*) (Renner and Day 2022).

Asian clams are an invasive species native to Asia that have spread widely in freshwater systems across North America and other parts of the world (Renner and Day 2022). Known for their rapid

reproduction and ability to form dense populations, Asian clams can outcompete native species, disrupt local ecosystems, and clog water intake pipes, leading to substantial ecological and economic impacts (Renner and Day 2022). They were first detected in 1948 in Lake Mead (Renner and Day 2022). The New Zealand mud snail is a small, invasive freshwater snail originally from New Zealand that has spread to various parts of the world, including North America and Europe (Renner and Day 2022). These snails reproduce rapidly and can form dense colonies, outcompeting native species for food and habitat, and disrupting local ecosystems by altering nutrient cycles and food webs. They were first reported north of Lake Mead in 2007 but continue to threaten downstream habitats (Renner and Day 2022). Another invasive snail (Malaysian trumpet snail [*Melanoides tuberculata*]) has been detected in Lake Mead, as well as other locations downstream (USGS 2025).

LCR MSCP Reach 2- Downstream of Hoover Dam to Lake Mohave

The Hoover Dam reach extends from the downstream end of Lake Mead, just downstream of Hoover Dam, and continues to Davis Dam, which impounds Lake Mohave. The extent of analysis for this reach is consistent with LCR MSCP Reach 2 and includes approximately 67 miles of riverine habitat (LCR MSCP 2004).

Lake Mohave is managed as a sport fishery by the states of Arizona and Nevada for largemouth bass, smallmouth bass, striped bass, rainbow trout, bluegill, green sunfish, channel catfish, and others (FWS 2018). Lake Mohave is operated by Reclamation as a reregulation reservoir. It fluctuates annually within a 15-foot vertical range, filling by mid-May and lowering to an annual minimum in October. Wave action redistributes sediment from desert washes and shapes it into sandbars or natural berms. In some areas, these sandbars isolate the lower portions of the desert washes from the lake proper, and when the lake is at full pool, lakeside ponds form. Reclamation and its partners in the Lake Mohave Native Fish Work Group have been using these lakeside ponds since 1992 to rear razorback suckers and bonytail (LCR MSCP 2024). As such, Lake Mohave serves as a fisheries backbone for razorback sucker and bonytail management in the Lower Colorado River.

Lake Mohave supports a diverse fishery, including striped bass, stocked rainbow trout, largemouth bass, smallmouth bass, bluegill, green sunfish, channel catfish, yellow bullhead, threadfin shad, gizzard shad, and common carp (**Table TA 8-2**). The native species present include bonytail and razorback sucker (**Table TA 8-2**). The lake was historically stocked year-round with rainbow trout until hatchery issues caused a pause from October 2013 to February 2017. Striped bass, introduced in the early 1980s, have become a major part of the sport fishery, preying on the stocked rainbow trout and other forage species, including shad, whose populations have declined due to predation (NDOW 2022).

Lake Mohave is home to the most genetically diverse population of razorback sucker left in the world, and as such is an important focus of the LCR MSCP (Marsh et al. 2015; LCR MSCP 2024). Because of the importance of preserving genetic diversity, and despite persistent challenges with the survival of repatriated razorback suckers, comprehensive genetic monitoring is conducted on wild-captured larvae, individuals reared in lakeside backwaters, and the repatriate adult population. These genetic monitoring efforts are ongoing (Bestgen et al. 2020; LCR MSCP 2024). The Lake Mohave population of razorback sucker spawns annually, but recruitment has not been documented since the 1950s (Marsh and Langhorst 1988; Mueller 2006; Karam and Marsh 2010). Striped bass, as well

as sunfish, may play a role in population declines throughout Lake Mohave (Karam and Marsh 2010; Kesner et al. 2012; Ehlo et al. 2017); predation of a 500 millimeter (mm; 19.7 inches) razorback sucker by striped bass was documented when an angler found an acoustic transmitter in a striped bass stomach. Sunfish have been implicated in the lack of young razorback sucker survival (FWS 2018). Renner and Day (2022) provide a historical account of all aquatic species detected in Lake Mead and Lake Mohave, but for purposes of this document, we plan to analyze species that have been routinely and recently documented by NDOW and AZGFD.

To combat the overall lack of razorback sucker recruitment in Lake Mohave and based on work done by the Lake Mohave Native Fish Work Group (Marsh et al. 2015), the LCR MSCP has maintained a stocking/augmentation program, providing for the stocking of up to 660,000 subadult razorback suckers and up to 620,000 subadult bonytail into the Lower Colorado River over a 50-year term. Since 2005, 137,030 bonytail have been stocked into Reaches 2 through 5. In addition, 157,990 razorback suckers have been stocked into Reach 2 during this period in support of maintaining the population in Lake Mohave as a genetic refuge for the species. This stocking rate is expected to meet the goals of the LCR MSCP Fish Augmentation Program (Bestgen et al. 2020; LCR MSCP 2024).

To obtain sufficient numbers of young fishes for grow-out and eventual stocking, an adult broodstock for each species is maintained by the LCR MSCP. Because the adult razorback sucker population in Lake Mohave is the most genetically diverse among razorback sucker populations, it is used as the primary broodstock for this species. Under the LCR MSCP, razorback sucker larvae are captured from this stock and reared at hatcheries in Arizona and Nevada before being stocked into Lake Mohave or other places within the Lower Colorado River. A second broodstock, developed from Lake Mohave offspring, is maintained at the Southwestern Native Aquatic Resources and Recovery Center in New Mexico, with additional rearing facilities in Arizona and Nevada (LCR MSCP 2024). The Southwestern Native Aquatic Resources and Recovery Center also maintains the world's only bonytail broodstock for species propagation, supported by a genetic management plan and funding for maintenance, augmentation, and distribution. A second bonytail broodstock is held at the Mora National Fish Hatchery as a refuge population to safeguard against catastrophic events. While stocked native fishes persist in some reaches of the Lower Colorado River, low post-stocking survival rates mean augmentation efforts remain focused on improving survival outcomes (LCR MSCP 2024).

Additionally, FWS, in collaboration with the LCR MSCP, maintains the Willow Beach National Fish Hatchery near the base of Hoover Dam. Under the LCR MSCP, offspring from Lake Mohave razorback sucker are captured directly from Lake Mohave and are reared at the Willow Beach National Fish Hatchery. These genetically diverse razorback suckers are then stocked back into the LCR MSCP reaches, including Lake Mohave, to help increase razorback sucker survival and recruitment bottlenecks created by nonnative fish predation and competition (LCR MSCP 2024).

Based on the captures reported in 2023, the repatriated population of razorback sucker in Lake Mohave appears stable to slightly increasing. It is thought that a combination of higher post-stocking and adult survival accounts for recent increases in population size. Post-stocking survival of smaller (less than 400 millimeters [mm; 15.7 inches] total length) fish continues to be low, but an increase in fish released at greater than 400 mm (15.7 inches) total length in recent years may

contribute to higher-than-average post-stocking survival (Reap et al. 2023; LCR MSCP 2024). Survival of razorback suckers in the Lower Basin is overall low and follows a size-at-release curve, as outlined in Schooley and Marsh (2007).

The razorback sucker population in Lake Mohave was recently estimated from two data sources: (1) trammel net capture data obtained during the annual, multiagency March roundup and (2) remote PIT scanning data collected during the sample year. Based on trammel net capture data, the repatriate population estimate for Lake Mohave was 1,720 individuals (95 percent confidence interval [CI], 950–3,440). Based on 2022–2023 remote PIT scanning, the lake-wide Lake Mohave repatriate population was estimated at 5,761 individuals (95 percent CI, 5,590–5,931). Subpopulation estimates using zone-specific scanning were also calculated and estimated the basin (reservoir miles 13–29) population at 3,295 individuals (95 percent CI, 3,173–3,416) and the river (reservoir miles 43–63) population at 3,603 individuals (95 percent CI, 3,379–3,826) (LCR MSCP 2024).

Reclamation and its partners in the Lake Mohave Native Fish Work Group have been using lakeside ponds since 1992 to rear razorback suckers and bonytail. The ponds are stocked with juvenile fishes each year as the reservoir fills (typically stocked in late January), and the LCR MSCP monitors and manages the ponds throughout the growing season. This work includes periodic monitoring of plankton production; removal of weeds and debris; population monitoring using remote sensing technologies; and routine monitoring of physical, chemical, and biological parameters. The ponds are normally harvested in late spring and again in the fall as the lake elevation declines. Fishes from these ponds are then released back into Lake Mohave or elsewhere within the Lower Colorado River. While annual pond harvests can be variable, lake-wide monitoring has consistently shown higher long-term contact rates for pond-reared versus hatchery-reared razorback suckers in Lake Mohave. Pond rearing provides an opportunity for fish to attain larger sizes prior to release into the lake, and contact data suggest that this larger size may improve post-stocking survival, increasing the likelihood that these fish will contribute to the adult broodstock (LCR MSCP 2024).

Bonytail, the other ESA-listed fish species within Reach 2 (Lake Mohave), were not stocked in 2024. In fact, within the past 20 years, approximately 3,500 bonytail have been stocked into Lake Mohave. This species is monitored through ongoing razorback sucker netting and PIT scanning efforts with a few capture records over time (J. Stolberg, LCR MSCP, personal communication). No recent population or survival estimates have been calculated for bonytail in Lake Mohave (or within any other reach of the Lower Colorado River) due to limited contacts and the overall rarity in terms of survival of this species in the Lower Basin (LCR MSCP 2024).

Currently, all reservoirs, lakes, and watersheds receiving raw Colorado River water have been exposed to quagga mussels (Renner and Day 2022; CDFW 2024). Asian clams and the New Zealand mud snail continue to threaten downstream habitats (Renner and Day 2022). Renner and Day (2022) also indicate that freshwater shrimp (*Gammarus fasciatus*) and big-ear radix (*Radix auricularia)* have established populations in Lake Mohave. The invasive Malaysian trumpet snail is also known from locations downstream of Lake Mead (USGS 2025).

LCR MSCP Reach 3- Davis Dam to Parker Dam

The LCR MSCP's Reach 3 extends from Davis Dam (RM 276) to Parker Dam (RM 192.3), including Lake Havasu up to full-pool elevation. This reach comprises a riverine component and a reservoir component (Lake Havasu). The Bill Williams River is a notable tributary draining into Lake Havasu, providing diversity in inflow habitats, including potentially important aquatic habitats, areas of vegetative cover, and, at times, turbidity near the inflow. In 2008, multiple agencies, including Reclamation, NDOW, and the Southern Nevada Water Authority, collaborated to secure the Boy Scout Camp property, incorporating it into the LCR MSCP as the Big Bend Conservation Area (LCR MSCP 2024). This effort resulted in the creation of 15 acres of backwater habitat beneficial to native fish species like razorback suckers, bonytail, and flannelmouth suckers in Reach 3 of the LCR MSCP. The area, located approximately 30 miles south of Laughlin, Nevada, is crucial for sustaining the flannelmouth sucker population. These represent some of the LCR MSCP's areas of interest and the typical habitats created by this program for the benefit of ESA-listed fishes.

Reach 3 contains ESA-listed fishes, including the razorback sucker and bonytail. An important population of flannelmouth sucker (a LCR MSCP covered species and an Arizona species of greatest conservation need) can also be found within this reach of the Lower Colorado River (**Table TA 8-2**) (LCR MSCP 2004). The Colorado River downstream of Davis Dam, to the inflow area of Lake Havasu, supports one of the largest populations of razorback sucker in the Lower Colorado River and is monitored by ongoing LCR MSCP and partner agency efforts (LCR MSCP 2024). This same area is also home to flannelmouth sucker, reintroduced in 1976 by AZGFD, and, for years, represented one of the most successful reintroductions of a native fish within the Lower Colorado River (Mueller and Wydoski 2004; Best and Lantow 2012). Reach 3 has also received bonytail stockings by the LCR MSCP (LCR MSCP 2024), although these bonytail stockings have produced little evidence of long-term survival, reproduction, or recruitment except for within isolated, predator-free environments (Marsh et al. 2024).

The reach 3 razorback sucker population in 2023 was estimated at 7,224 individuals (95 percent CI from 6,931 to 7,517). Survival of razorback suckers in the Lower Basin is overall low and appears to follow a size-at-release curve, as outlined in Schooley and Marsh (2007), with larger fish, even those with a total length greater than 500 mm (19.7 inches), having higher survival. This is the largest population estimate for razorback suckers in Reach 3 since program implementation began in 2005. Due to the limited number of bonytail and flannelmouth suckers detected, no recent population estimates have been generated for those species (LCR MSCP 2024). Recent surveys have suggested that flannelmouth sucker captures are unfortunately becoming quite rare in the Lower Colorado River, and it remains a species of concern (J. Stolberg, LCR MSCP, personal communication; LCR MSCP 2024). A total of 2,764 razorback suckers and 2,070 bonytail were stocked into Reach 3 during 2023 (LCR MSCP 2024).

The LCR MSCP currently collects larval razorback sucker from Lake Mohave to rear at various hatcheries and lakeside ponds on Lake Mohave. The result of these efforts, as well as larvae reared at the Southwest Native Aquatic Resources and Recovery Center hatchery, provides razorback sucker of sufficient size and quantity to stock this species into Reach 3. Similarly, bonytail, from hatchery sources supported by the LCR MSCP, are also stocked into Reach 3. Capture and contact data for Reach 3 are acquired through multiple projects, ongoing multiagency native fish roundups, and from

other annual surveys conducted by LCR MSCP partners. Fall and spring netting surveys are conducted throughout Topock Gorge and upper Lake Havasu. PIT scanners are used, and active sampling within the Mohave Valley Conservation Area, a 63-acre backwater created by the LCR MSCP, is also conducted to support understanding of the fish community in Reach 3. Backwater habitats created in Reach 3 by the LCR MSCP will continue to be connected to the mainstream river to address the life-history requirements of flannelmouth suckers, as well as other native fishes. Finally, there are numerous projects dedicated to habitat creation and conservation efforts, for and on behalf of the LCR MSCP fish species in this reach, as further outlined within LCR MSCP (2024). The Colorado River downstream of Davis Dam is the lowermost reach of the river managed by the AZGFD Region III Aquatics Program. This portion of the Colorado River from Davis Dam (RM 276.0) to the Interstate 40 crossing (RM 233.9) at Topock, Arizona, corresponds with the LCR MSCP's Reach 3. Lake Havasu is managed as a sport fishery by the state of Arizona, which supports populations of largemouth bass, smallmouth bass, striped bass, bluegill, and redear sunfish (*Lepomis microlophus*). Other nonnatives present in Lake Havasu, but which are not actively managed, include green sunfish, yellow bullhead, flathead catfish, and channel catfish (**Table TA 8-2**) (FWS 2018). More specifically, during routine electrofishing trend surveys in 2024, AZGFD captured redear sunfish, bluegill, gizzard shad, largemouth bass, green sunfish, common carp, sunfish hybrids (*Lepomis* spp.), striped bass, smallmouth bass, flathead catfish, black crappie, goldfish (*Carassius auratus*), threadfin shad, yellow bullhead, and channel catfish (**Table TA 8-2**) (AZGFD 2024a). In 2021, AZGFD conducted a creel census in the upper portion of this reach, from Davis Dam (RM 276) to the Avi Bridge crossing (RM 257). This survey reports that the fishery primarily consists of rainbow trout, striped bass, and channel catfish. Other species included smallmouth bass, largemouth bass, sunfishes (*Lepomis* spp.), common carp, razorback sucker, and the introduced population of flannelmouth sucker. Rainbow trout is the only sportfish species currently stocked in this reach, originating from Willow Beach National Fish Hatchery, and routinely being stocked into this location (**Table TA 8-2**) (AZGFD 2023).

Sampling in the 12 miles downstream of Davis Dam indicates that the sport fishery in this area is mainly supported by striped bass, largemouth bass, smallmouth bass, redear sunfish, and regularly stocked rainbow trout (NDOW 2020). Additionally, efforts to repatriate and monitor native species, such as the razorback sucker, bonytail, and flannelmouth sucker, are ongoing in the river and its backwaters. Although flannelmouth suckers are native to the Colorado River, they are believed to have been introduced to this specific section (Mueller and Wydoski 2004). Bonytail, while present in Lake Havasu, are not commonly found in this part of the river but occasionally appear in backwaters (NDOW 2020). Other species present include common carp, channel catfish, bluegill, and gizzard shad (**Table TA 8-2**) (Ozborn et al. 2021).

Anglers primarily target striped bass and rainbow trout. During the spring and early summer, striped bass migrate upstream from Lake Havasu to spawn, concentrating near the tailwater of Davis Dam, where their migration is halted (NDOW 2020). Catch rates for game fish in the surveyed section of the Colorado River typically increase with rising temperatures in the spring (Ozborn et al. 2021). Species diversity is higher in the backwaters, which tend to harbor large bass spp., and redear sunfish; while large striped bass are occasionally caught in the main channel of Laughlin Lagoon, but most are found in the river's main channel (Ozborn et al. 2021).

In 2021, largemouth bass in both the backwater and riverine areas were in very good condition; in contrast, striped bass appeared in poor to fair condition (Ozborn et al. 2021). Although anecdotal due to the small sample sizes, a representative sample would require at least 250 individuals per species. Sampling methods and management activities from downstream of Davis Dam to Parker Dam include trammel-netting, electrofishing, angler use, and harvest surveys (NDOW 2020).

The fish community of Topock Marsh includes self-sustaining populations of largemouth bass, channel catfish, black crappie, striped bass, bluegill, green sunfish, and redear sunfish. Gizzard shad were first caught in 2012 and are now the most abundant species sampled (**Table TA 8-2**). It should be noted that razorback suckers have been stocked into Topock Marsh five times since 2010 and have been caught every year since the first stocking, except in 2015 (AZGFD 2022).

A population of desert pupfish (*Cyprinodon macularius*) occurs at Bill Williams National Wildlife Refuge in a constructed and maintained pond established in 2006. In all cases of pupfish presence in the Lower Basin, ponds were established with the intent to provide outreach and educational opportunities, as well as to provide replicates for the El Doctor/Santa Clara Slough lineage of desert pupfish and a source for stockings and augmentations of additional sites. In the construct of the 1993 pupfish recovery plan (FWS 1993) and the 2019 amendment to the recovery plan (FWS 2019a), these highly managed artificial ponds are considered to be tier 3 replicates that contribute to the required number of replicates (by pupfish lineage) necessary for desert pupfish to be downlisted or delisted. As such, these ponds are an important conservation tool that contributes to recovery (FWS 2012).

Flathead catfish are of particular concern as they are voracious predators and pose a substantial threat to native fishes of the Lower Colorado River. This species appears to be expanding its use of habitats within Reach 3 (potentially due to temperature) and is routinely monitored by U.S. Fish and Wildlife Service (FWS) personnel. Through 2022, this species had been captured nearly as far upstream as the area between Needles and Fort Mohave in the Lower Colorado River (near Boundary Cone Road crossing) (Rasset and Love-Chezem 2024).

Since quagga mussels were discovered in Lake Mead in Nevada in 2007, subsequent surveys have found smaller numbers of quagga mussels in Lake Havasu and in the Colorado River Aqueduct System, which serves Southern California. Currently, all reservoirs, lakes, and watersheds receiving raw Colorado River water have been exposed to quagga mussels at this point (Renner and Day 2022; CDFW 2024). Crayfish (various species) are invasive freshwater crustaceans originally introduced as fishing bait and for biological control of aquatic vegetation (Renner and Day 2022; AZGFD 2024b) and are assumed to be present within Reach 3. The Asian clam was first detected in 1948 in Lake Mead and threatens downstream ecosystems (Renner and Day 2022); thus, present within Reach 3. As with upstream reaches, the New Zealand mudsnail and Malaysian trumpet snail continue to be a threat (Renner and Day 2022; USGS 2025).

LCR MSCP Reaches 4 and 5- Parker Dam to Imperial Dam

The Colorado River within the LCR MSCP Reaches 4–5, extending from Parker Dam (RM 192.3) to Imperial Dam (RM 49.2), represents the lowest combined reach regularly sampled by the LCR MSCP. This section was historically characterized as a wide, turbid river abundant in sediment,

featuring large woody debris and lacking large boulders (Mueller and Marsh 2002; Mueller et al. 2005). It operated as a dynamic ecosystem influenced by extreme water temperature fluctuations (0–35°C; 32–95°F) and by fluctuations between flooding and drought that shaped the life histories of native Colorado River fishes (Reclamation 2004; Mueller 2006).

Today, this reach of the river extends roughly 100 miles south to Yuma, AZ, and is heavily utilized for recreation, particularly boating and other activities (Mueller and Marsh 2002). It has been notably altered, becoming a channelized waterway that often spans up to 10 miles, predominantly used for agricultural purposes (Mueller and Marsh 2002). The original riparian landscape, characterized by large willows and cottonwood trees, has been replaced by tamarisk due to altered flood management practices, resulting in salt crusts on the ground from inadequate drainage (Mueller and Marsh 2002).

The introduction of nonnative fish species has substantially displaced native fauna throughout much of the area (Mueller 2006). However, some native fish populations persisted in isolated habitats such as the Cibola High Levee Pond, a 5-acre oxbow pond semi-connected to the mainstream river. This pond provided a refuge for native fish species, allowing them to survive despite the challenges posed by nonnative species (Mueller and Marsh 2002; Mueller 2006). Today, Cibola High Levee Pond contains an important wild, recruiting population of bonytail. Additionally, Imperial Ponds Conservation Area, an 80-acre pond complex created by the LCR MSCP, also provides predator-free habitats for razorback sucker and bonytail (Kesner et al. 2012). Similar to Cibola High Levee Pond, these ponds have experienced successful spawning and recruitment of native fishes; however, nonnative fish invasions remain a threat (Kesner et al. 2012). Such environments also serve as crucial research sites for biologists studying the dynamics of native fish populations in altered river ecosystems (Mueller 2006).

Currently, this reach contains ESA-listed fishes, including the razorback sucker and bonytail (**Table TA 8-2**); each is primarily sustained by stocking efforts. Although stocked native fish have been found to persist in this reach, research and monitoring have shown that post-stocking survival rates are low. Therefore, native fish augmentation efforts will continue to focus on improving post-stocking survival (LCR MSCP 2024). From 2007–2023, a total of 152,515 razorback suckers and 65,303 bonytail were stocked in reaches 4–5 (LCR MSCP 2024). Many of the bonytail stocked appeared to disperse downstream, while razorback sucker appeared to disperse upstream of the stocking location. Both species often utilize backwater habitats; however, razorback sucker also use riverine habitats (Kelley et al. 2022). Bonytail post-stocking survival has been low and often immeasurable (Heishman et al. 2023), and bonytail mortality is likely high immediately after stocking (Kelley et al. 2022). On the other hand, razorback sucker stockings have seemed more successful with population growth and relatively high post-stocking survival (0.44–0.85) in this location (Heishman et al. 2023). The population estimate was 2,208 in 2023 (95 percent CI: 2,062–2,355), the largest population estimate in this reach since the stocking program's inception in 2005 (LCR MSCP 2024). Native fish management in these reaches has primarily focused on off-channel, predator-free habitats and stocking efforts.

The LCR MSCP currently collects larval razorback sucker from Lake Mohave to rear at various hatcheries. These efforts, as well as larvae reared at the Southwest Native Aquatic Resources and Recovery Center, provide razorback sucker of sufficient size and quantity to stock this species into

Reach 4–5. Similarly, bonytail, from hatchery sources supported by the LCR MSCP, are also stocked into Reach 4–5. Backwater habitats created in this reach by the LCR MSCP will continue to be disconnected from the mainstream river to address the life-history requirements of bonytail and razorback suckers. There are several projects, such as those at Cibola High Levee Pond and the Imperial Ponds Conservation Area, dedicated to habitat creation, backwater disconnection, manipulation, and conservation efforts, for and on behalf of the LCR MSCP fish species in this reach (LCR MSCP 2024).

The AZGFD Region IV Aquatics Program is responsible for managing the area corresponding to the LCR MSCP Reach 4–5. The nonnative fishery primarily consists of striped bass, channel catfish, smallmouth bass, largemouth bass, sunfishes (*Lepomis* spp.), common carp, red shiner, fathead minnow, crappie (*Pomoxis* spp.), shad (*Dorosoma* spp.), goldfish, bullhead (*Ameiurus* spp.), and blue tilapia (*Oreochromis aureus*) (Renner and Day 2022; Ham 2023a, 2023b; Ramey and Ham 2024). Flathead catfish have been found in the Lower Basin since at least the 1960s, and the most recent surveys reported their presence, a particular concern for native fishes due to their predatory nature (**Table TA 8-2**) (FWS 2019b; Rasset and Love-Chezem 2024).

There are no natural, extant populations of desert pupfish (*Cyprinodon macularius*) currently present in or along the Lower Colorado River. Historically, the species occurred in the Lower Colorado River and its floodplain downstream of Lake Mead. More recently, desert pupfish in the Lower Colorado River region occurred only in managed refugia populations maintained in artificial ponds at national wildlife refuges. Two small human-made ponds were constructed at Cibola and Imperial National Wildlife Refuges to support refugia populations derived from captive stock originally sourced from Mexico. The refugia pond at Cibola is located adjacent to the refuge headquarters on higher ground outside the historical floodplain and is supplied by the refuge's potable water system, which diverts water from the Colorado River using a pump. Desert pupfish are currently present only at the Cibola pond; individuals were temporarily moved there from the Imperial pond while repairs are completed at the refuge, and fish may be returned in the future. In all cases of pupfish presence in the Lower Basin, these ponds were established with the intent to provide outreach and educational opportunities, as well as to provide replicates for the El Doctor/Santa Clara Slough lineage of desert pupfish and a source for stockings and augmentations of additional sites. In the construct of the 1993 pupfish recovery plan (FWS 1993) and the 2019 amendment to the recovery plan (FWS 2019a), these highly managed artificial ponds are considered to be tier 3 replicates that contribute to the required number of replicates (by pupfish lineage) necessary for desert pupfish to be downlisted or delisted. As such, these ponds are an important conservation tool that contributes to recovery (FWS 2012). Because these populations occur in isolated, managed refugia outside the river channel and historical floodplain, they do not represent extant wild populations within the Lower Colorado River system. Management of the refugia ponds occurs separately from Lower Colorado River water management activities addressed under the LCR MSCP, and desert pupfish are therefore not associated with riverine habitats in the LCR action area.

Crayfish are invasive freshwater crustaceans originally introduced as fishing bait and biological control for aquatic vegetation (Renner and Day 2022; AZFG 2024b). Mueller et al. (2005) observed red swamp crayfish (*Procambarus clarkii*) predating on bonytail and razorback sucker eggs in Cibola High Levee Ponds. Additionally, quagga mussels and Malaysian trumpet snail, which are known

from locations within and downstream of Lake Mead, are also found in Reaches 4–5 (Renner and Day 2022; CDFW 2024; USGS 2025).

LCR MSCP Reaches 6 and 7– Imperial Dam to the SIB
Due to the overall low numbers of native and ESA-listed fishes and their low survival, coupled with current LCR MSCP fish sampling efforts being allocated primarily down through Reaches 4–5 (J. Stolberg, LCR MSCP, personal communication 2025; LCR MSCP 2024), we present information from Reaches 4–5 as the lowest-most combined reach routinely sampled (from Parker Dam [RM 192.3] to Imperial Dam [RM 49.2]). We will not present data for Reaches 6–7 of the LCR MSCP. We note that historical literature provides at least some semblance of species present in this reach (**Table TA 8-2**).

TA 8.2 Environmental Consequences

TA 8.2.1 Methodology

Decision Making Under Deep Uncertainty Modeling
To assess future alternatives and management strategies, a modeling analysis known as Decision Making under Deep Uncertainty (DMDU; see **Section 3.2.6**, Decision Making Under Deep Uncertainty and **Appendix E**, DMDU Overview and Approach, for additional details) was applied to systematically evaluate potential system responses across a wide range of plausible futures. The analysis incorporated five alternative scenarios (No Action, Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven Alternatives [both LB Priority and LB Pro Rata approaches]) and one Representative Preferred Alternative, which represents various flow conditions and the continuation of current flow management strategies from Lake Powell (Continued Current Strategies [CCS] Comparative Baseline). The modeling originally included three initial conditions (Dry, Mid, and Wet) across 400 hydrologic traces, resulting in 1,200 modeled futures. For the Final EIS, the Wet and Mid initial conditions and all associated modeled futures were removed. Only the Dry initial condition and its associated futures are retained. The Representative Preferred Alternative will focus on the analysis of the first 10 years of impacts, given its 10-year implementation period, which will begin with low reservoir elevations in 2027 and relatively poor initial decade performance in many threshold analyses.

These modeled scenarios are designed to span a broad spectrum of uncertainty, allowing examination of the impacts on aquatic habitats and resources under several alternatives and baseline conditions. By evaluating outcomes across these alternative futures, DMDU offers a rigorous approach to quantifying changes in habitat extent for both lake and riverine environments. This method enables detailed interpretation of data, such as lake elevations and flow conditions under each scenario, to assess the impacts on spawning and habitat availability relative to historic conditions. If an alternative achieves a robustness score of 90 percent or higher, it can be considered truly robust with respect to a particular resource. When the difference in robustness between alternatives exceeds 10 percent, one alternative can be considered more robust than another. If the difference is less than 10 percent, the alternatives are considered similarly robust. Models were considered based on a multiagency cooperation of resource impacts.

DMDU figures are presented to provide comprehensive and reliable information about potential system outcomes under each alternative, regardless of future uncertainties. By intentionally disconnecting the analysis from probabilistic interpretation, these figures focus attention on key resource concerns and improve our understanding of how each alternative performs across a range of hydrologic conditions, and are presented to provide comprehensive and reliable information about potential system outcomes under each alternative, regardless of future uncertainties.

Conditional Box Plots

The conditional boxplots serve as a visual tool to summarize the range of potential resource impacts for each alternative under varying hydrologic conditions, categorized by the 3-year average Lees Ferry natural flow preceding each simulated year. This averaging period balances capturing both persistent moderate hydrology and annual extremes, with five flow categories chosen to reflect historic conditions and stakeholder perspectives. The boxplots illustrate how each alternative responds to these hydrologic scenarios, especially under challenging conditions like drought, enabling direct comparison of resource impacts. By highlighting the variability and distribution of responses, the figures allow readers to infer connections between system history and outcomes. Because resource data points within each category are determined by hydrology rather than modeling outcomes, readers can compare relationships between different resources across conditional boxplots, and, where relevant, multiple variables may be displayed together to further illuminate system responses under different alternatives.

Robustness Heat Maps

Robustness heat maps evaluate how each alternative performs across a wide range of future scenarios over extended modeling periods, such as decades or the entire simulation horizon (2027–2060). Unlike conditional boxplots, which assess each year independently, heatmaps aggregate results based on resource-specific definitions of "acceptability," using thresholds and frequencies to classify scenarios as successful or unsuccessful. Each alternative is assigned a robustness score, indicating the percentage of futures in which the performance criteria are met, with higher scores indicating greater robustness. The heatmaps display multiple levels of performance, from the most challenging criteria at the top to less stringent criteria downstream of and use a highlighted row to emphasize key acceptability thresholds or significant comparison points. This color-coded format distills complex modeling results into an accessible, comparative framework, enabling readers to quickly compare alternatives, understand their relative robustness, and make informed decisions.

Vulnerability Bar Plots

Vulnerability bar plots display, for each alternative, the hydrologic conditions, based on a 10-year Lees Ferry natural flow statistic, under which threshold outcomes are classified as preferred minimum performance (blue) or undesirable (red), such as during the worst 10-year drought. This visual division highlights the specific scenarios that lead to vulnerability, with larger blue regions indicating greater robustness. Accompanying boxplots provide context by relating these vulnerability thresholds to recent observations and a wide range of plausible future scenarios. The primary purpose of the vulnerability bar plot is to clarify the conditions under which an alternative is likely to fail and to determine whether those conditions fall within what can reasonably be anticipated, thereby informing decision-makers about each alternative's limits and resilience.

Lake Powell

To assess the impacts of reservoir elevations in Lake Powell on fish populations and aquatic habitats—including critical habitats for the Colorado pikeminnow and razorback sucker—we drew on multiple data sources, combining monitoring, reporting, and spatial analysis methods. Annual catch data for sportfish, collected from various monitoring programs, were analyzed alongside other datasets to track changes in lake habitat quality and quantity as water levels declined. Monitoring and distribution data for endangered Colorado pikeminnow and razorback sucker, including abundance and expansion into newly formed riverine inflows, are sourced from the Utah Division of Wildlife Resources and the Upper Colorado River Basin and San Juan River Basin Recovery Implementation Programs. These programs also provide information on spawning habitat locations and the abundance of razorback sucker larvae, which are monitored to detect shifts in spawning sites and potential bathymetric tipping points that could limit habitat availability. Stage-to-habitat descriptions and relationships derived from scientific literature were used to evaluate habitat and fish species abundance. Stage-to-habitat descriptions link stage height (e.g., water surface elevation) to the amount and type of habitat available to fish. Surface area and longitudinal analyses were used to quantify changes in habitat extent for both lake and riverine environments, with data interpretation (e.g., lake elevation by alternative) using DMDU analysis. Additionally, the smallmouth bass model (Eppehimer et al. 2025; Eppehimer and Yackulic 2026) was used to determine entrainment of smallmouth bass at Glen Canyon Dam and the probability of entrainment based on Lake Powell elevation. The smallmouth bass model was developed by the U.S. Geological Survey (USGS) in collaboration with partners, including the Reclamation and AZGFD, as part of the Glen Canyon Dam Adaptive Management Program. The model was developed to evaluate how variables, such as water elevation, temperature, and velocity, affect smallmouth bass population dynamics. Entrainment refers to fish being drawn into and carried through water management structures such as dam intakes, pumps, or turbines, often resulting in injury, death, or unintended movement into new habitats. Together, these methodologies enable a comprehensive assessment of how reduced reservoir elevations impact sportfish, endangered native fish, and their critical habitats in Lake Powell and its inflows.

Glen Canyon Dam to Lake Mead

To assess the impacts of modified releases from Glen Canyon Dam down the Colorado River to Lake Mead, a multi-faceted methodology was employed. Habitat availability and species abundance for threatened and endangered native fishes, including humpback chub and razorback sucker, as well as other native species (e.g., flannelmouth sucker, bluehead sucker) and nonnative species (rainbow trout, brown trout, smallmouth bass) were evaluated using stage-to-habitat descriptions and relationships derived from the scientific literature. These descriptions explain how changes in flow or water level (stage) create or reduce habitats, including backwaters, side channels, riffles, or shorelines that different species need for spawning, rearing, or feeding. Monitoring data and reports from agencies such as the Grand Canyon Monitoring and Research Center, the FWS, AZGFD, and the NPS provided empirical evidence on changes in habitat and fish abundance by life stage, particularly in the Lees Ferry sub-reach. Predictive modeling tools included the smallmouth bass model, applied to predict escapement from Lake Powell, entrainment through Glen Canyon Dam, and subsequent survival downstream Eppehimer et al. 2025; Eppehimer and Yackulic 2026). Additionally, the conservation measures for humpback chub outlined in the LTEMP BO, including

the specific triggers that require management action, were incorporated to guide management decisions and evaluate the effectiveness of mitigation efforts. Together, these methods and the DMDU approach described in **Section 3.2.6**, Decision Making under Deep Uncertainty, enabled a comprehensive assessment of how flow modifications impact fish communities and habitats from Glen Canyon Dam to Lake Mead.

Lake Mead to SIB

To assess the impacts of reservoir elevations from Lake Mead downstream to the SIB on fish, other aquatic species, and their habitats, a comprehensive methodology was employed, integrating agency monitoring, habitat analysis, and species-specific evaluations. Annual and seasonal reports, along with monitoring data from agencies, including Reclamation, the LCR MSCP, AZGFD, NDOW, and Grand Canyon Monitoring and Research Center, were used to track changes in habitat quantity and quality for lake, wetland, and riverine environments. These data sources provided information on the distribution and abundance of sportfish, ESA-listed, and other native species (humpback chub, razorback sucker, bonytail, flannelmouth sucker, and desert pupfish) across newly expanded inflow zones and affected sub-reaches. The methodology included the analysis of Colorado River Simulation System (CRSS) data to identify changes in Lake Mead shoreline area (spawning and nursery habitats) and longitudinal habitat assessments to quantify habitat expansion or contraction throughout the Lower Colorado River system. CRSS is a long-term planning model developed and maintained by Reclamation, used to simulate how water moves through the Colorado River system under different inflow, demand, and management scenarios (for additional details see **Section 3.2,** Analysis Methods and **Appendix A**). Particular focus was placed on known spawning sites and critical habitats, as well as how changes in water quantity, release timing, temperature, and quality from Hoover Dam affect downstream riverine habitats.

The alternative analysis approach for Lower Basin fishes was based on the observation that native and nonnative fish populations have persisted through the interim guideline operational period (2008 to present), with ongoing multi-year drought, declining reservoir storage, and revised Colorado River management strategies (Reclamation 2007). Flow and water quality data from this period were thoroughly documented and analyzed (see **TA 3**, Hydrologic Resources and **TA 6**, Water Quality). The guiding principle for fisheries analysis assumed that populations capable of surviving under these historic conditions would likely persist under similar future scenarios. Using the DMDU approach, the analysis evaluated whether the Final EIS alternatives could produce future conditions, such as flows, lake elevations, and habitat availability, outside the historical range observed from 2008 to 2025. All relevant data were assessed using established DMDU procedures and CRSS modeling (see **TA 3**, Hydrologic Resources for details). This integrated, historically informed approach enabled a robust evaluation of how changing reservoir conditions could affect fish populations and aquatic habitats across the analysis area.

Impact Analysis Area

The impact analysis area includes the Colorado River corridor from the full-pool elevation of Lake Powell to the SIB as described in **Sections 3.2**, Analysis Methods. The issues analyzed under this section are specific to defined boundaries within the larger study area, as delineated in **Table TA 8-2**.

Assumptions

- There will be modifications in quantity, timing, temperature, and quality of water released from Glen Canyon Dam and Hoover Dam through the Lower Colorado River. Fish habitats, distributions, and abundances are likely influenced by changes in flows, with reduced flows and variations in dam releases potentially altering available habitat and population numbers.
- Backwaters and riverine native fish habitats are likely affected by reduced flows.
- Known spawning sites of razorback sucker may be affected by reduced flows. Analyses involving models (CRSS and smallmouth bass) will be conducted in collaboration with model developers and users from various cooperating agencies.
- Lake Powell reservoir elevations lower than 3,570 feet are likely to increase entrainment of smallmouth bass and other nonnative fish that would likely result in negative effects on humpback chub and other native fish in the action area.
- LCR MSCP reaches may be combined for analysis due to the lack of special status species, habitat, operations, and management.
- Ongoing fisheries management practices conducted by the various agencies in the Colorado River Basin would be similar and ongoing into the future.

Impact Indicators

- Abundance and location of razorback sucker larvae throughout the project area.
- Elevation where spawning habitat may become limited (if available) throughout the project area.
- Changes in annual monitoring of catches of sportfish throughout the project area.
- Changes in available habitat and abundances of native fish species by life stage throughout the project area.
- Changes in backwater areas at flow stages in the Lower Colorado River Basin (Lower Basin).
- Changes in distribution and abundance of Colorado pikeminnow and razorback sucker with expanded inflows in Lake Powell.
- Changes in distribution and abundance of humpback chub with expanded inflow habitats in Grand Canyon.
- Changes in electrofishing monitoring catch rates and angler catch rates of rainbow trout and brown trout in Lees Ferry sub-reach.
- Changes in fish habitat and/or fish distribution and numbers based on dam releases and flows throughout the project area.
- Changes in razorback sucker spawning site areas and suitability at flow stages in the Lower Basin.
- Reduction in Colorado pikeminnow and razorback sucker critical habitat in the Colorado River and San Juan River inflows to Lake Powell with increased elevation of Lake Powell.
- Changes to razorback sucker critical habitat, which is the full pool of Lake Mead.
- Increased numbers of smallmouth bass escaping through Glen Canyon Dam and increased distribution and numbers of smallmouth bass downstream.
- Changes in salinity concentration in the Lower Basin.

- Lower reservoir elevation changes to shoreline spawning and nursery habitat for razorback sucker throughout the project area.
- Lake Powell elevation below 3,666.5 feet to sustain Piute Farms Waterfall as a nonnative fish barrier.
- Lake Mead elevation below 1,090 feet to sustain Pearce Ferry Rapid as a nonnative fish barrier, but above 1,000 feet to protect the power pool.
- Reduced abundance and distribution of desert pupfish in the Lower Basin.
- Reduced abundance and distribution of tilapia and other fish species in the Lower Basin.
- Reduced water quality from nitrates and selenium, resulting in algal blooms and fish die-offs in the Lower Basin.
- Reduced wetland area and river inflow habitat in the Lower Basin.

TA 8.2.2 Issue 1: Lower Lake Powell reservoir elevations have reduced lake habitat and extended the inflows of the Colorado River and San Juan River by approximately 35 miles each. How will changes in flow impact the quantity and quality of lake, wetland, and riverine inflow habitats?

The most important threats to ESA-listed native fish associated with Lake Powell operations relate to the establishment and spread of nonnative fish-eating (piscivorous) fish, particularly smallmouth bass. Reservoir elevation plays an important role in these risks. Lower lake elevations increase the likelihood that smallmouth bass are entrained through Glen Canyon Dam and establish downstream populations, where they may increase predation and competition pressures on native fish, including humpback chub and other species targeted for recovery in the Colorado River Basin. Lake elevation also determines whether Piute Farms Waterfall on the San Juan River functions as a barrier preventing nonnative fish from moving upstream from Lake Powell into riverine habitats.

Consistent with these processes, the most important Impact Indicators for Lake Powell, in order of importance, are: (1) increased numbers of smallmouth bass escaping through Glen Canyon Dam and expanded distribution and abundance of smallmouth bass downstream, (2) maintaining Lake Powell elevation below 3,666.5 feet to sustain Piute Farms Waterfall as a nonnative fish barrier, (3) reduction in Colorado pikeminnow and razorback sucker riverine (lotic) critical habitat in the Colorado River and San Juan River inflows to Lake Powell with increased reservoir elevation, and (4) increase in shoreline habitat of rock cliffs and rock falls that favor spawning, growth, and recruitment of smallmouth bass in Lake Powell. The first two indicators represent the primary threats to native fish populations because they directly influence the potential growth, spread, and invasion of nonnative piscivorous fish upstream and downstream.

Lower reservoir elevations also reduce lake habitat for sportfish, which may negatively affect recreational fisheries but can shift habitat conditions in ways that favor smallmouth bass and increase predation pressure on native fish. Impact indicators associated with these processes include rates of smallmouth bass entrainment at Glen Canyon Dam, changes in the distribution and abundance of smallmouth bass downstream, alterations in upstream passage at Piute Farms Waterfall, variations in the distribution and abundance of Colorado pikeminnow and razorback sucker in river inflow areas, and changes in annual sportfish catches.

Piute Farms Waterfall serves as a barrier to the upstream movement of nonnative fish from Lake Powell into the San Juan River, reducing predators and competitors in upstream habitats used by native fish. However, the waterfall also prevents razorback sucker and Colorado pikeminnow that move or are transported downstream of the falls from returning upstream to historic and designated critical habitat. Reservoir elevation, therefore, influences both the effectiveness of this barrier and the connectivity between Lake Powell and upstream river habitats.

Reservoir elevation also affects the extent of riverine inflow habitat in the Colorado and San Juan Rivers upstream of Lake Powell. Lower lake levels expose longer segments of riverine habitat, including designated critical habitat for Colorado pikeminnow and razorback sucker, while higher elevations inundate portions of these reaches and convert them to reservoir conditions. Changes in the length of available riverine habitat represent a habitat effect that would primarily occur if Lake Powell refills and is evaluated separately from the risks associated with nonnative fish establishment and the loss of the Piute Farms Waterfall barrier.

Several key elevation thresholds are considered in this analysis. These include the elevation associated with increased risk of smallmouth bass entrainment at Glen Canyon Dam (3,570 feet; see smallmouth bass model in Eppehimer et al. 2025; Eppehimer and Yackulic 2026, **TA 8.2.3**), the elevation at which Piute Farms Waterfall becomes inundated and fish passage becomes possible (3,666.5 feet; Paul Grams, USGS/GCMRC, personal communication), the elevations at which designated critical habitat for Colorado pikeminnow and razorback sucker begins to inundate in the Colorado River inflow (3,598 feet) and San Juan River inflow (3,600 feet), and the elevation below which water can only be released through the river outlet works (3,490 feet). These thresholds help evaluate how reservoir operations may influence native fish persistence in Lake Powell and downstream of Glen Canyon Dam.

A relationship was developed linking the riverine lengths of the Colorado and San Juan Rivers and their inflows into Lake Powell to lake elevation (**Table TA 8-3**, **Table TA 8-4**). This analysis focuses on the designated critical habitat for Colorado pikeminnow and razorback sucker. Critical habitat for humpback chub and bonytail does not occur in these inflow areas. Critical habitat for Colorado pikeminnow and razorback sucker extends 33.5 miles of the Colorado River inflow from Rapid 25 (RM 201.5, full-pool elevation of Lake Powell at 3,700 feet) downstream to North Wash (RM 168, elevation of 3,598 feet). When Lake Powell rises above 3,598 feet, it begins to inundate designated critical habitat for Colorado pikeminnow and razorback sucker, converting lotic, riverine habitat to more lentic, lake habitat. A similar relationship was developed for critical habitat on the San Juan River inflow that extends 39 miles from upstream of the Clay Hills boat ramp (RM 63.5, full-pool elevation) downstream to Neskahai Canyon (RM 24.5) (**Table TA 8-4**). These species, especially the Colorado pikeminnow, prefer riverine habitats when available (FWS 2018, 2022), and extending riverine inflow benefits the species.

In **TA 3**, Hydrologic Resources, **Figure TA 3-6** analyzed water year minimum Lake Powell elevations for each alternative and the CCS Comparative Baseline under varying hydrologic categories. The categories are defined by the preceding 3-year average Lees Ferry natural flow and show how elevations change due to hydrologic conditions. Below, the modeled elevations are compared to critical elevations related to habitat and passage.

Table TA 8-3
Estimated Linear Miles of Colorado Pikeminnow and Razorback Sucker Critical Habitat at Varying Lake Powell Elevations (in feet) in the Colorado River Inflow

Colorado River Inflow	River Mile	Elevation	Critical Habitat Inundated (River Miles)
Rapid 25	201.5	3,700	33.5
Imperial Canyon	200	3,690	32
Gypsum Canyon	196.6	3,680	28.6
Clearwater Canyon	192	3,660	24
Bowdie Canyon	190.6	3,658	22.6
Cove Canyon	186	3,640	18
Dark Canyon	183	3,625	15
Sheep Canyon	177	3,610	9
Narrow Canyon	173	3,604	5
Dirty Devil River	169.5	3,602	1.5
North Wash	168	3,598	0

Note: River miles of critical habitat are computed from the relationship y= 0.3178x - 972.22 (R2 = 0.97), where x = lake elevation, y = river mile. River miles are measured upstream of Lees Ferry.

Table TA 8-4
Estimated Linear Miles of Colorado Pikeminnow and Razorback Sucker Critical Habitat at Varying Lake Powell Elevations (in feet) in the San Juan River Inflow

San Juan River Inflow	River Mile	Elevation	Critical Habitat Inundated (River Miles)
5.5 miles upstream of Clay Hills Boat Ramp	63.5	3,700	39
Clay Hills Boat Ramp	58	3,690	33.5
Piute Falls Waterfall-top	54.5	3,666	30
Piute Falls Waterfall-bottom	53.5	3,638	29
Mikes Canyon	50.5	3,632	26
Copper Canyon	45	3,627	20.5
Nokai Creek	42	3,626	17.5
Great Bend	29.5	3,605	5
Neskahai Wash	24.5	3,600	0

River miles of critical habitat are computed from the relationship y=0.3363x - 1177.8.22 (R2=0.81), where x = lake elevation, y = river mile. River miles are measured upstream from the historic confluence of the San Juan and Colorado Rivers.

In the Average Flow Category, only the Enhanced Coordination and Maximum Operational Flexibility Alternatives yield median elevations above 3,598 feet, at 3,613 feet and 3,604 feet, respectively. This indicates that these two alternatives result in the Colorado River inflow being partially inundated greater than 50 percent of the time in the Average Flow Category. For the remaining alternatives and the CCS Comparative Baseline, only the 75th or higher percentile elevations exceed 3,598 feet, indicating that, in the Average Flow Category, inundation of the Colorado River inflow does occur but less frequently than in the Enhanced Coordination and Maximum Operational Flexibility Alternatives.

In the Critically Dry Flow Category, the 90th percentile elevations are below 3,598 feet for all alternatives and the CCS Comparative Baseline, ranging from 3,509 feet (Supply Driven Alternative [both LB Priority and LB Pro Rata approaches]) to 3,595 feet (Enhanced Coordination Alternative). This indicates that the Colorado River inflow is not inundated in at least 90 percent of years in the Critically Dry Flow Category.

The results are practically the same when considering critical habitat in the San Juan River inflow, which is only 2 feet higher at 3,600 feet.

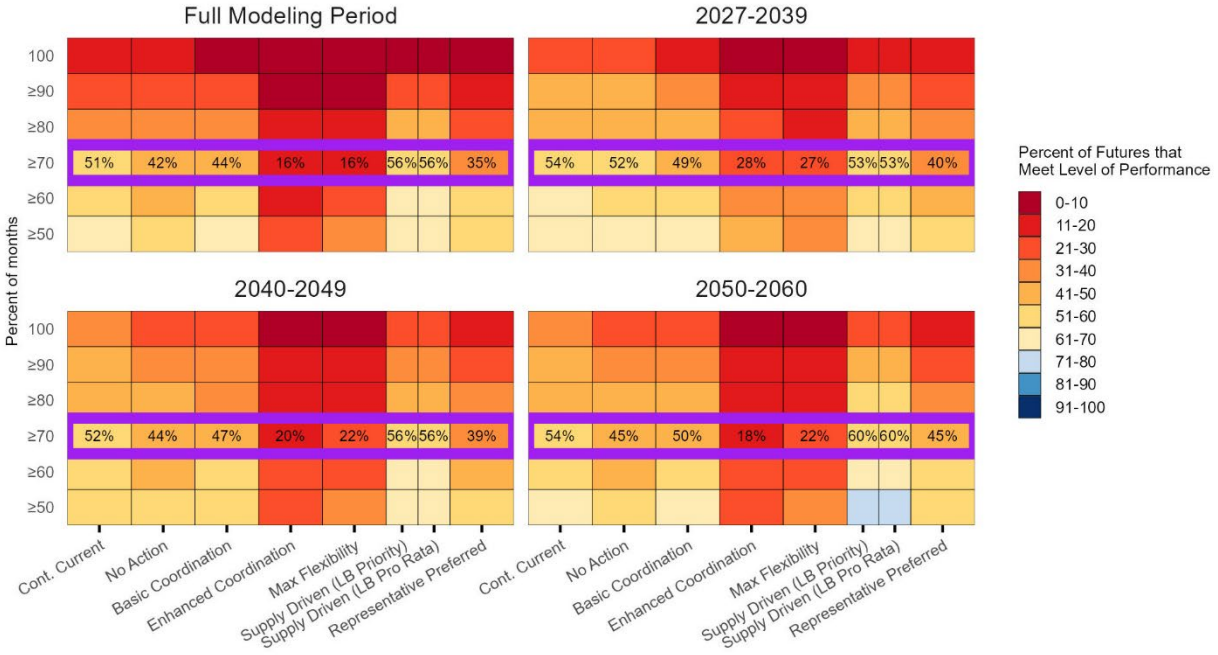
Figure TA 8-1 below depicts the ability of each alternative (columns) to maintain Lake Powell elevations below 3,598 feet in the specified percent of months (rows). Four modeling periods are shown to capture the full modeling period: 2027–2039, 2040–2049, and 2050–2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative keeps elevations below 3,598 feet at least 70 percent of months. 70 percent serves as a historical benchmark, as Lake Powell's elevation was below 3,598 feet in 66.7 percent of months in the recent decade (October 2015 to March 2026).

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at protecting critical habitat for Colorado pikeminnow and razorback sucker in the Colorado River inflow. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard.

Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust, satisfying the preferred minimum performance level in only 16 percent of modeled futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust, meeting the preferred minimum performance level in 56 percent of futures. Notably, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the only option that outperforms the CCS Comparative Baseline, which meets the preferred minimum performance level in 51 percent of futures. With respect to decadal results, the Enhanced Coordination and Maximum Operational Flexibility Alternatives continue to be the least robust over the three decadal periods. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) continues to be the most robust in all three decadal periods and meets the highest performance level of 60 percent in the last decade (2050–2060).

The Representative Preferred Alternative meets the preferred minimum level of 3,598 feet in 35 percent of modeled futures in the full modeling period. Based on the planned length of this decision,

Figure TA 8-1
Inundation of Critical Habitat of Colorado Pikeminnow and Razorback Sucker by Colorado River Inflow: Robustness.
Percentage of futures in which the Lake Powell elevation is below 3,598 feet in the percentage of months specified by each row

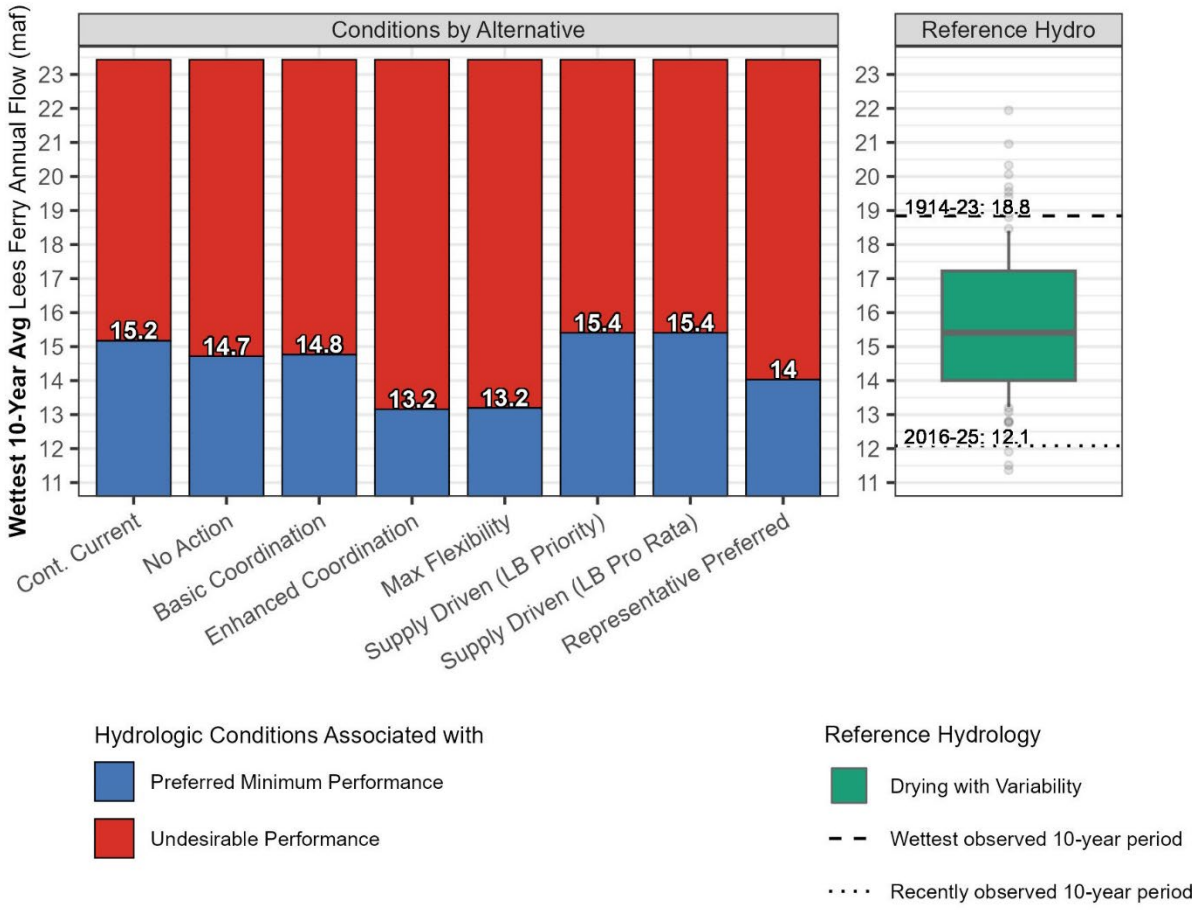


it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are similarly robust, meeting the preferred minimum performance in 49-54 percent of futures. The Representative Preferred Alternative is in the middle at 40 percent of futures, and the Enhanced Coordination (28 percent) and Maximum Operational Flexibility (27 percent) Alternatives are the least robust.

Figure TA 8-2 below shows what flow conditions are likely to result in Lake Powell elevations above 3,598 feet more than 30 percent of months. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-1** above, which defined a future as successful when an alternative maintained elevations below 3,598 feet at least 70 percent of months.

For this vulnerability analysis, the wettest 10-year average Lees Ferry natural flow was a skillful predictor of undesirable performance. The vulnerability threshold for each alternative is described and compared with the reference hydrology ensemble using this streamflow summary statistic. The reference hydrology panel shows the range of median 10-year average flows represented in the Drying with Variability ensemble, which represents how hydrologic conditions may change in a warmer future, along with the most recent observed 10-year period. The median value of the Drying with Variability ensemble is approximately 15.5 maf, and the most recent 10-year average Lees Ferry annual flow (12.1 maf) is shown as a dotted line for comparison.

Figure TA 8-2
Inundation of Critical Habitat of Colorado Pikeminnow and Razorback Sucker by Colorado River Inflow: Vulnerability.
Conditions that could cause Lake Powell to go above 3,598 feet in more than 30 percent of months



Modeling results indicate that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are likely to meet the preferred minimum performance level when the median 10-year average flow is less than 13.2 maf per year. Because nearly 90 percent of traces in the Drying with Variability ensemble exceed these values, these alternatives are expected to produce Lake Powell elevations above 3,598 feet in more than 30 percent of months unless future conditions are substantially drier than recent history.

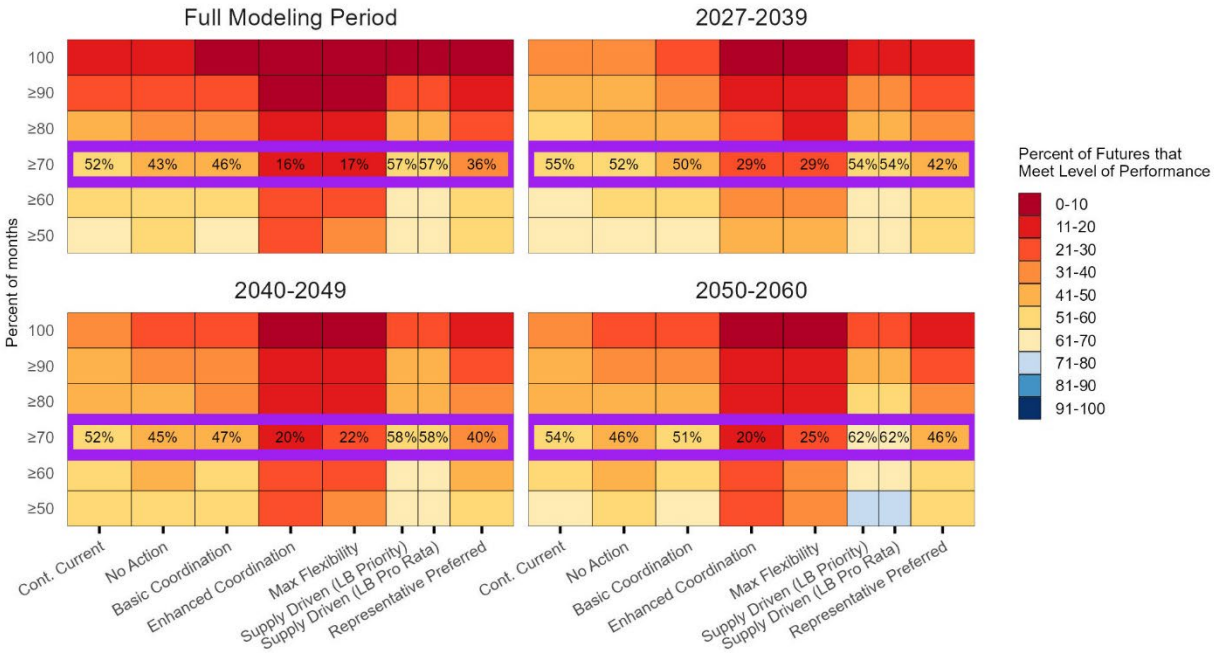
The remaining action alternatives have thresholds between about 15.4 and 14.7 maf. Lake Powell elevations would be more likely to achieve the preferred minimum performance if flows like the recently observed 10-year period (12.1 maf) continue, thus helping maintain critical habitat for Colorado pikeminnow and razorback sucker in the Colorado River inflow. This represents a potential reduction in available riverine habitat if Lake Powell refills; however, it is distinct from the more immediate population-level risks associated with the establishment of nonnative piscivorous fish.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Powell elevation above 3,598 feet more than 30 percent of the time if the wettest 10-year average Lees Ferry annual flow is greater than 14.0 maf. This alternative may or may not be vulnerable in the next 10 years because of the conflict in different aspects of the reference hydrology panel. Considering the Drying with Variability ensemble, greater than 50 percent of traces are greater than 14.0 maf, suggesting this alternative is reasonably likely to be vulnerable. However, the recently observed 10-year period is below 14.0 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Figure TA 8-3 below depicts the ability of each alternative to maintain Lake Powell elevations below 3,600 feet in the specified percent of months. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative keeps elevations below 3,600 feet at least 70 percent of months. 70 percent serves as a historical benchmark, as Lake Powell's elevation was below 3,600 feet in 68.3 percent of months in the recent decade (October 2015 to March 2026).

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at protecting critical habitat for Colorado pikeminnow and razorback sucker in the San Juan River inflow. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard.

Figure TA 8-3
Inundation of Critical Habitat of Colorado Pikeminnow and Razorback Sucker by San Juan River Inflow: Robustness.
Percentage of futures in which the Lake Powell elevation is below 3,600 feet in the percentage of months specified by each row



Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust, satisfying the preferred minimum performance level in only 16 percent and 17 percent of modeled futures, respectively. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust, meeting the preferred minimum performance level in 57 percent of futures. Notably, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the only option that outperforms the CCS Comparative Baseline, which meets the preferred minimum performance level in 52 percent of futures. The decadal results show similar performance and ranking of alternatives.

The Representative Preferred Alternative meets the preferred minimum performance level in 36 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are similarly robust, meeting the preferred minimum performance in 50-55 percent of futures. The Representative Preferred Alternative is in the middle at 42 percent of futures, and the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust (both 29 percent).

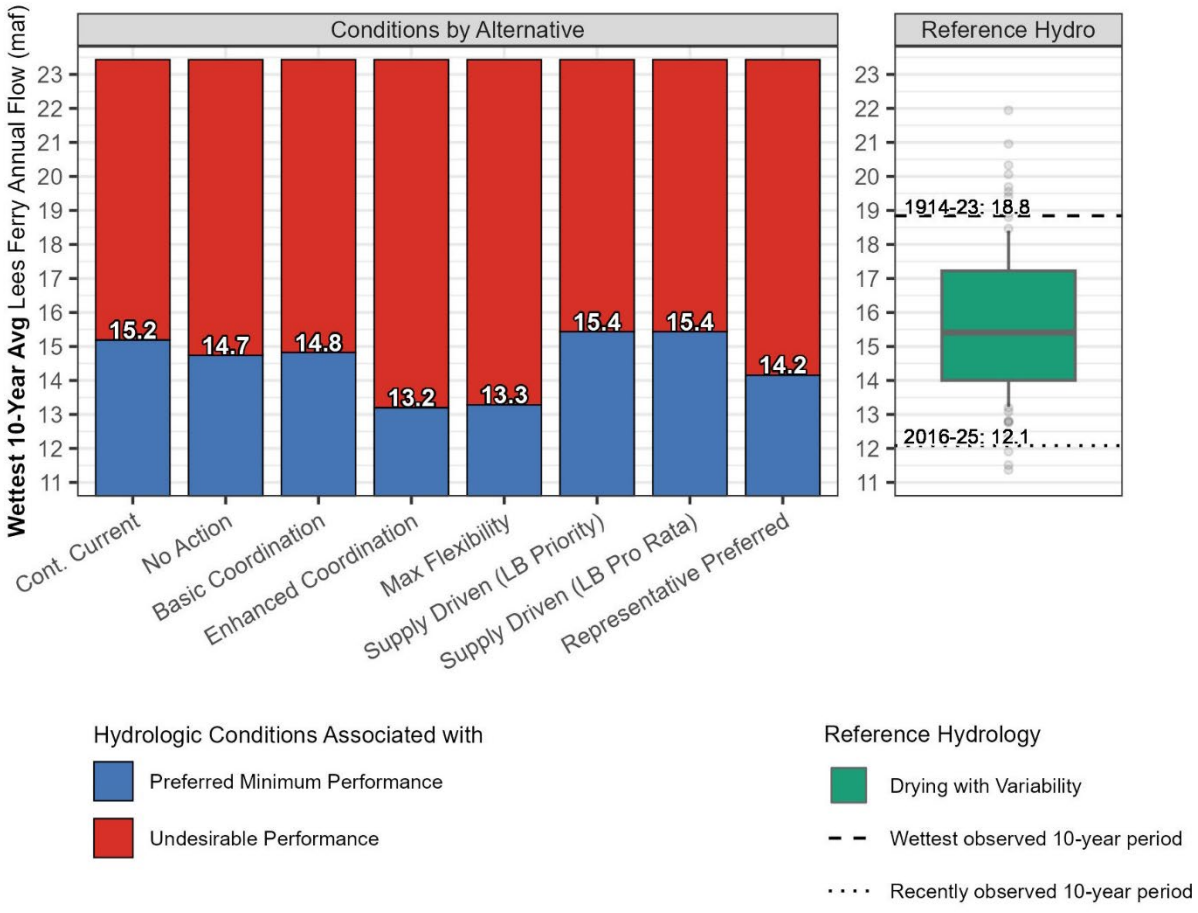
Figure TA 8-4 shows what flow conditions are likely to result in Lake Powell elevations above 3,600 feet more than 30 percent of months. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-3** above, which defines a future as successful when an alternative maintains elevations below 3,600 feet at least 70 percent of months. Elevations above this threshold inundate critical habitat for Colorado pikeminnow and razorback sucker in the San Juan River inflow.

For this vulnerability analysis, the wettest 10-year average Lees Ferry natural flow was a skillful predictor of undesirable performance. The median value of the Drying with Variability ensemble, which represents how hydrologic conditions may change in a warmer future, is approximately 15.4 maf. The most recent 10-year average Lees Ferry annual flow (12.1 maf) is shown as a dotted line for comparison.

If the future has a wettest 10-year average flow greater than 13.2 maf, Enhanced Coordination Alternative modeling results indicate undesirable performance. If the future has a wettest 10-year average flow greater than 13.3 maf, the Maximum Operational Flexibility Alternative modeling results indicate undesirable performance. Unless future hydrology is similar to or drier than the most recent 10-year average, these alternatives are expected to result in Lake Powell elevations above 3,600 feet in approximately 30 percent of months.

Modeling results indicate that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are likely to meet the preferred minimum performance level when the median 10-year average flow is less than 13.2 maf and 13.3 maf per year, respectively. Because nearly 90 percent of traces in the Drying with Variability ensemble exceed these values, these alternatives are expected to produce Lake Powell elevations above 3,600 feet in more than 30 percent of months unless future conditions are substantially drier than recent history.

Figure TA 8-4
Inundation of Critical Habitat of Colorado Pikeminnow and Razorback Sucker by San Juan River Inflow: Vulnerability.
Conditions that could cause Lake Powell to go above 3,600 feet in more than 30 percent of months



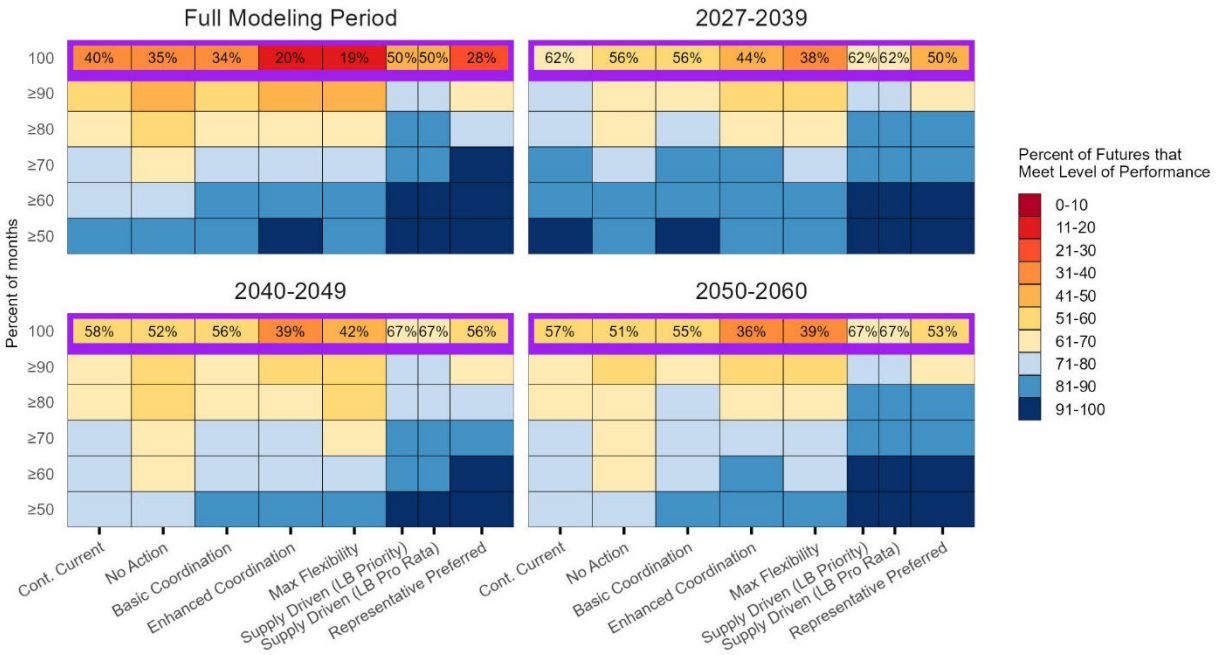
The remaining action alternatives have thresholds between about 15.4 and 14.7 maf. Between 25 and 75 percent of traces in the Drying with Variability ensemble have a median 10-year average above these values. Lake Powell elevations would be more likely to achieve the preferred minimum performance if flows like those observed during the recent 10-year period (12.1 maf) continue, thereby helping maintain critical habitat for Colorado pikeminnow and razorback sucker in the San Juan River inflow. Inundation of this habitat reduces its suitability and may decrease fish abundance, survival, and reproductive potential.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Powell elevation above 3,600 feet more than 30 percent of the time if the wettest 10-year average Lees Ferry annual flow is greater than 14.2 maf. This alternative may or may not be vulnerable in the next 10 years because of the conflict in different aspects of the reference hydrology panel. Considering the Drying with Variability ensemble, greater than 50 percent of traces are greater than 14.2 maf, suggesting this alternative is reasonably likely to be vulnerable. However, the recently

observed 10-year period is below 14.2 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Below, **Figure TA 8-5** evaluates the robustness of each alternative with respect to Paiute Farms Waterfall continuing to function as a barrier. The figure reports the percentage of modeled futures for each alternative in which Lake Powell elevation is below 3,666.5 feet in the percentage of months specified by each row. The highlighted row identifies the preferred minimum performance level: that Lake Powell elevation remains below 3,666.5 feet in 100 percent of months within each modeled future. Staying below this elevation ensures that Piute Farms Waterfall continues to function as a barrier, preventing both native and nonnative fish from moving upstream from the reservoir into the San Juan River's historical riverine habitat. Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at maintaining this barrier and preventing upstream fish movement. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard.

Figure TA 8-5
Piute Farms Waterfall remains a barrier to upstream fish passage: Robustness. Percentage of futures in which the Lake Powell elevation is below 3,666.5 feet in the percentage of months specified by each row



Over the full modeling period, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the best, satisfying the preferred minimum performance level in 50 percent of modeled futures. This is higher than the CCS Comparative Baseline, which meets the preferred minimum performance level in 40 percent of futures. The results indicate that maintaining Lake Powell's elevation below 3,666.5 feet in every month over the next 34 years may be difficult. If the performance level is relaxed to require elevations below 3,666.5 feet in at least 90 percent of months,

performance improves substantially. Under this condition, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the CCS Comparative Baseline meet the performance level in more than 71 percent and 51 percent of futures, respectively. Similar alternative rankings are observed when analyzed by decade, with improved performance across all alternatives.

The Representative Preferred Alternative meets the preferred maximum level of 3,666.5 feet in 28 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are similarly robust, meeting the preferred minimum performance in 56-62 percent of futures. The Representative Preferred Alternative is in the middle at 50 percent of futures, and the Enhanced Coordination (44 percent) and Maximum Operational Flexibility (38 percent) Alternatives are the least robust.

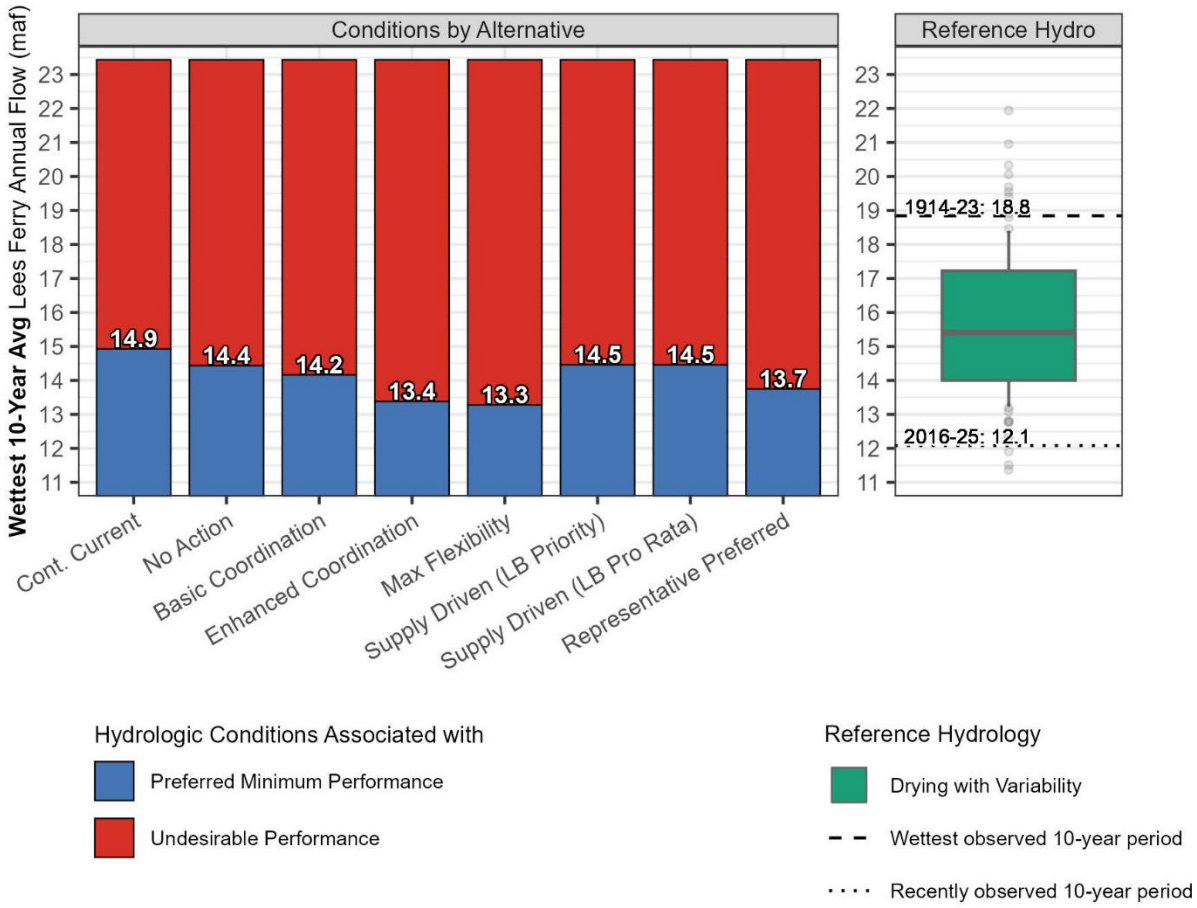
When the elevation of Lake Powell is above 3,666.5 feet, the Piute Farms Waterfall on the San Juan River becomes inundated, allowing fish to move above the waterfall from Lake Powell into the San Juan River. This would allow native fish to access historical riverine habitat, which could benefit their populations. But these same conditions would also allow nonnative fish to access the river as potential predators and competitors of native fish.

Figure TA 8-6 shows which flow conditions are likely to result in one or more instances of Lake Powell exceeding 3,666.5 feet. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-5** above, which defines a future as successful when an alternative maintains elevations below 3,666.5 feet 100 percent of the time since elevations above this threshold can inundate the Piute Farms Waterfall.

The wettest 10-year average Lees Ferry natural flow was identified as a skillful predictor of undesirable performance. The reference hydrology panel shows the range of the wettest 10-year average flows represented in the Drying with Variability ensemble, along with the most recent observed 10-year period. The Drying with Variability median value is approximately 15.4 maf, and the most recent 10-year average Lees Ferry annual flow (12.1 maf for 2016–2025) is shown as a dotted line for comparison.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most vulnerable, with futures that experience a 10-year average greater than 13.4 and 13.3 maf expected to result in at least one occurrence of elevation above 3,66.5 feet. 10-year averages above these values have occurred historically, and about 90 percent of traces in the Drying with Variability ensemble experience a 10-year average wetter than these thresholds. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Basic Coordination Alternative, No Action Alternative, and the CCS Comparative Baseline are less vulnerable, with 10-year averages of 14.2–14.9 maf or wetter expected to result in undesirable performance. Between 50 and 75 percent of traces in the Drying with Variability ensemble experience a 10-year average wetter than these thresholds.

Figure TA 8-6
Piute Farms Waterfall remains a barrier to upstream fish passage: Vulnerability. Conditions that could cause Lake Powell elevation to go above 3,666.5 feet in 1 or more Months



Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to one or more occurrences of Lake Powell elevation above 3,666.5 feet if the wettest 10-year average Lees Ferry annual flow is greater than 13.7 maf. This alternative may or may not be vulnerable in the next 10 years because of the conflict in different aspects of the reference hydrology panel. Considering the Drying with Variability ensemble, about 75 percent of traces are greater than 13.7 maf, suggesting this alternative is reasonably likely to be vulnerable. However, the recently observed 10-year period is below 13.72 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

While maintaining the Piute Farms Waterfall as a fish barrier could reduce the effectiveness of river population augmentation efforts (e.g., entrainment of native fish over the waterfall into Lake Powell) and may influence long-term genetic diversity of native fish, it is still considered a net benefit for native fish recovery. Preventing upstream movement of predatory nonnative species, such as striped bass, largemouth bass, and walleye, is critical to protecting recovery efforts. To mitigate impacts on native species, the San Juan River Basin Recovery Implementation Program currently funds manual

translocation of native fish from below the falls to above them and is working to secure funding for a selective fish passage structure that would support native fish movement at this site in the future.

Table TA 8-5 shows the area of inundated shoreline habitat (in acres) at different elevations of Lake Powell, based on the relationship from Root and Jones (2022). The analysis quantifies how changes in lake elevation influence the availability of nearshore habitat. At higher lake elevations, the shoreline typically consists of cobble/gravel benches and shallow, vegetated areas. At lower elevations, the shoreline is primarily steep cliff faces and rock falls. Higher lake levels tend to favor popular sportfish, like largemouth bass, bluegill, and crappie, whereas lower levels favor smallmouth bass (Gustaveson 2018). Expansion of these nonnative sportfishes will likely add predation pressure to native fishes, with the smallmouth bass likely having the highest impact (Eppehimer et al. 2025).

Table TA 8-5
Estimated Acres of Shoreline Habitat at Varying Lake Powell Elevations

Elevation of Lake Powell (Feet)	Inundated Shoreline Habitat (Acres)	Available Shoreline Habitat (Acres)
3,700	160,784	0
3,680	145,647	13,900
3,660	130,899	27,110
3,640	118,054	39,880
3,620	105,929	51,700
3,600	95,387	62,920
3,580	85,667	73,240
3,560	75,981	82,580
3,540	67,206	91,690
3,520	59,476	99,640
3,500	52,386	106,600
3,490	44,883	109,790

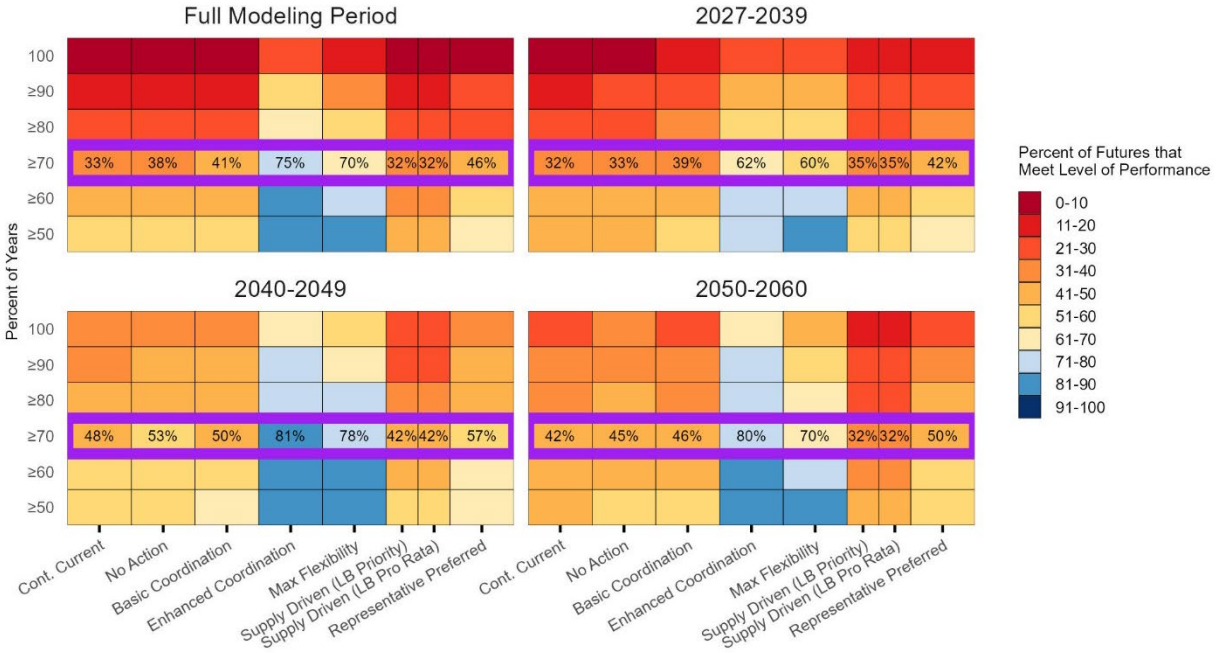
Source: Root and Jones 2022
Note: Acres of habitat are computed from the relationship $y=0.00113145734416358*X^3+(-0.9757039*X^2) + (35570.7021*X) + (-38508306.3)$ ($R^2 = 0.9998$), where x=lake elevation, y=acres of inundated shoreline (relationship from Root and Jones [2022]).

In the Average Flow Category for water year maximums, 90 percent, and 75 percent interquartile ranges for all alternatives other than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), are projected to increase inundation of shoreline habitat around Lake Powell (see **Figure TA 3-6**, Water Year Minimum and End of Water Year (EOWY) Elevations and Storage Volumes of Lake Powell, in **TA 3**, Hydrologic Resources). The increase or decrease (-) in shoreline habitat (acres) for each alternative, compared to the CSS Comparative Baseline, is the No Action Alternative (7,484), the Basic Coordination Alternative (-9,286), the Enhanced Coordination Alternative (-2,187), the Maximum Operational Flexibility Alternative (-732), and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches; -18,740). Lower reservoir elevations for all alternatives will result in shorelines with steep cliffs and rockfalls that favor smallmouth bass reproduction and recruitment, thereby increasing the population and the risk of entrainment and

additional predation pressures on humpback chub and other native fish downstream of Glen Canyon Dam.

Figure TA 8-7 below shows the ability of each alternative to maintain October 1 Lake Powell elevation above 3,570 feet in the percentage of years specified by each row. The highlighted row identifies the preferred minimum performance level: that the October 1 Lake Powell elevation remains above 3,570 feet in at least 70 percent of years within each modeled future. This threshold reflects recent historical conditions, as the October 1 elevation was above 3,570 feet in seven of ten years from 2016 to 2025, or 70 percent of years.

Figure TA 8-7
Smallmouth Bass Entrainment: Robustness.
Percentage of futures for each alternative in which the October 1st Lake Powell elevation is above 3,570 feet in percent of years specified by each row



Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at reducing the risk of entraining smallmouth bass from the Glen Canyon Dam forebay and allowing them to escape into the Colorado River downstream of the dam. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective and could increase the likelihood that smallmouth bass become more abundant in the Lees Ferry sub-reach and potentially further downstream, increasing predation and competition pressures on native fish, particularly the threatened humpback chub.

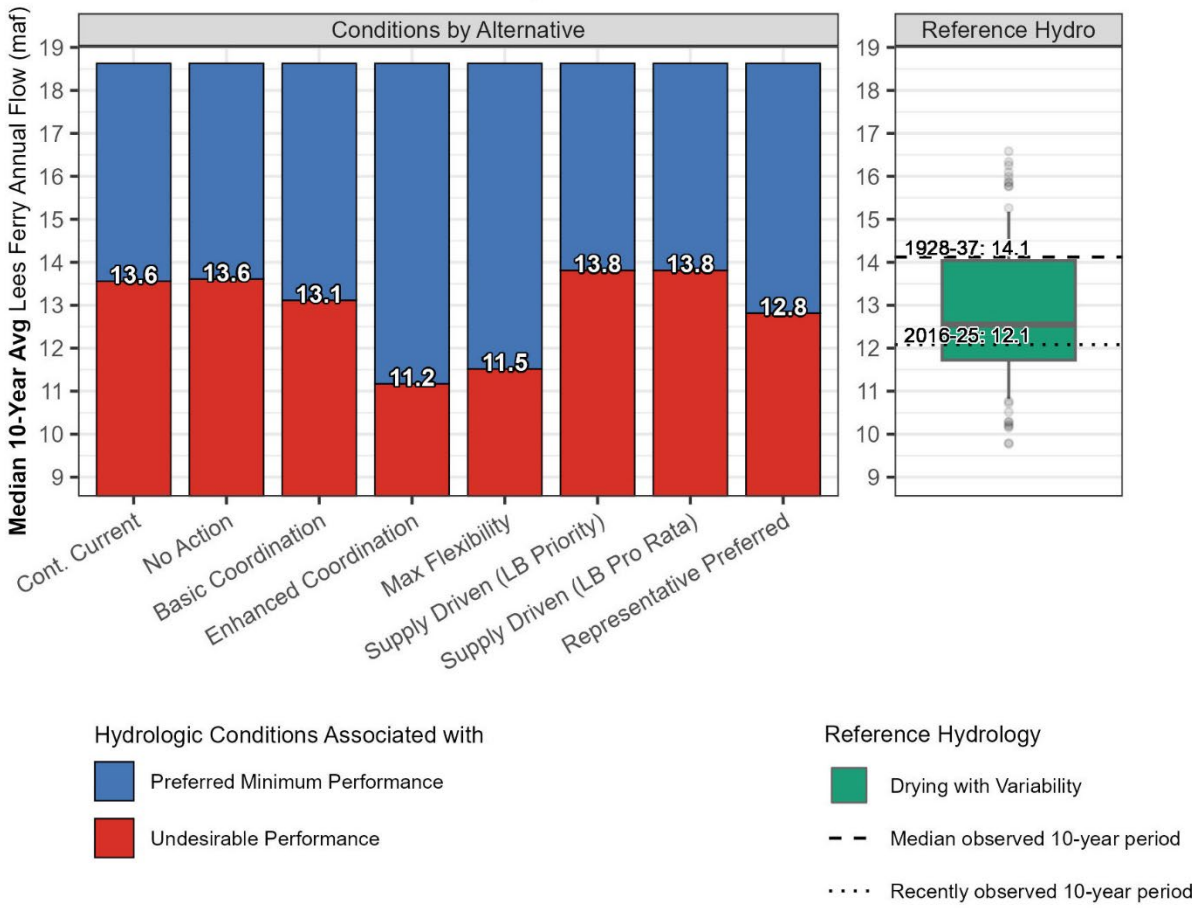
Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, satisfying the preferred minimum performance level in 75 percent and 70 percent of futures, respectively. The remaining alternatives and the CCS Comparative Baseline perform substantially worse, meeting the preferred minimum performance level in only 32

to 41 percent of futures. Similar alternative rankings are observed when analyzed by decade, with improved performance across all alternatives.

The Representative Preferred Alternative meets the preferred minimum performance level in 46 percent of futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination (62 percent) and Maximum Operational Flexibility (60 percent) Alternatives are the most robust, followed by the Representative Preferred Alternative (42 percent). The remaining alternatives are less robust, meeting the preferred minimum performance level in 32-39 percent of futures.

Figure TA 8-8 below shows what flow conditions are likely to result in October 1st Lake Powell elevation falling below 3,570 feet more than 30 percent of years. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-7** above, which defines a future as successful when an alternative maintains elevations above 3,570 feet at least 70 percent of the time to reduce the risk of entraining smallmouth bass through Glen Canyon Dam.

Figure TA 8-8
Smallmouth Bass Entrainment: Vulnerability.
Conditions that could cause the October 1 Lake Powell Elevation to go below 3,570 feet in more than 30 percent of years



For this vulnerability analysis, the median 10-year average Lees Ferry natural flow was a skillful predictor of undesirable performance. The median value of the Drying with Variability ensemble, which represents how hydrologic conditions may change in a warmer future, is approximately 12.5 maf. The most recent median 10-year average Lees Ferry annual flow (12.1 maf) is shown as a dotted line for comparison.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to median 10-year averages of 11.2 and 11.5 maf, which are significantly lower than the other alternatives. Less than 25 percent of the Drying with Variability traces have a median 10-year average this dry, so it is reasonably unlikely these alternatives will result in October 1st elevations below 3,570 feet more than 30 percent of the time. The remaining action alternatives and CCS Comparative Baseline are vulnerable to undesirable performance for median 10-year averages between 13.1 and 13.8 maf. Greater than 50 percent of traces in the Drying with Variability ensemble exhibit flows drier than this, indicating these alternatives are reasonably likely to result in October 1st elevation below 3,570 feet more than 30 percent of the time. In other words, they could produce October 1 elevations below 3,570 feet more frequently than observed in recent decades, increasing the likelihood that smallmouth bass could move through Glen Canyon Dam into the Colorado River. Increased presence of smallmouth bass in the Lees Ferry sub-reach and potentially farther downstream could elevate predation and competition pressures on native fish, including the threatened humpback chub.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to October 1st Powell elevation below 3,570 feet more than 30 percent of years under a median 10-year average of 12.8 maf. This alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in more than 50 percent of the traces in the Drying with Variability ensemble, which represents a drier future.

TA 8.2.3 Issue 2: Changes in water quantity, release timing, temperature, and quality from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry.

The reach of the Colorado River from Glen Canyon Dam to Lake Mead has undergone ecological changes due to modifications in water quantity, timing, temperature, and quality resulting from dam operations. These changes have affected the habitats and populations of both native and nonnative fish species throughout the Grand Canyon. Of particular concern are the threatened humpback chub and endangered razorback sucker, whose survival and abundance are closely tied to flow regimes and habitat availability. Other native species, such as flannelmouth sucker and bluehead sucker, as well as sportfish such as rainbow trout, are similarly affected by altered river conditions. As the elevation of Lake Powell decreases, the epilimnion, the warm, well-mixed surface water where most fish reside, aligns more closely with the dam's penstocks. The reduction in water elevation increases the likelihood that nonnative fish, such as smallmouth bass, will be entrained, pass through the dam, and enter the Colorado River downstream. Results from entrainment modeling (Eppehimer et al. 2025) suggest that propagule pressure increases dramatically when elevations are below 3,530. If reservoir elevations fall below 3,510 feet, the risk persists as long as water continues to be released through the penstocks (3,490 feet). Once below 3,490 feet, the risk of invasion declines as water is released through the river outlet works. Under current dam

operations, the model predicts that maintaining reservoir elevations above 3,570 feet at the start of the year would substantially reduce the risk of entraining smallmouth bass and other undesirable nonnative species (Eppehimer et al. 2025). Additionally, as Lake Powell's water level declines, warmer water from the epilimnion is released through the dam, resulting in higher downstream water temperatures. These warmer water conditions are likely to facilitate the reproduction and establishment of warmwater nonnative fish that pose a major threat to ESA-listed fish species and other native and sportfish living downstream of Glen Canyon Dam. If highly predatory smallmouth bass were to establish themselves downstream of the dam, removal efforts would be difficult and expensive, with potentially limited success.

To analyze these issues, a suite of biological and ecological indicators and metrics was used. Results of the hydrologic CRSS model were used to evaluate the effects of flows on aquatic resources. Preliminary quantitative models integrating information on smallmouth bass population dynamics, potential entrainment rates, water temperature, and other variables to assess invasion risk and potential management options for smallmouth bass were also used. Key indicators include changes in available habitat and species abundance by life stage, shifts in catch rates for rainbow trout and brown trout in the Lees Ferry sub-reach, and the capture of smallmouth bass downstream of Glen Canyon Dam.

A key metric for this analysis is water temperature thresholds at Lees Ferry, the Little Colorado River confluence, the Havasu Creek confluence, and Pearce Ferry along the river's longitudinal extent between Glen Canyon Dam and Lake Mead. For humpback chub, temperatures below 12 °C (53.6 °F) limit or inhibit growth while temperatures above 16 °C (60.8 °F) allow for mainstream spawning (Valdez and Speas 2007). For smallmouth bass, 16 °C (60.8 °F) was analyzed as temperatures near or exceeding 16 °C (60.8 °F) promote successful spawning (Bestgen and Hill 2016). For trout species, 20 °C (68 °F) was used as the thermal threshold at which trout exhibit stress and mortality, with brown trout more tolerant than rainbow trout at temperatures above 20 °C (68 °F; Valdez and Speas 2007).

The smallmouth bass model was used to predict both propagule pressure, defined as the number of smallmouth bass entrained or passing through Glen Canyon Dam, and downstream lambda (λ, [population growth rate]) based on factors such as Lake Powell elevation, temperature, inflow volumes, and outflows (Yackulic et al. 2024; Eppehimer et al. 2025; Eppehimer and Yackulic 2026). The model provides predictions for propagule pressure estimated at Glen Canyon Dam and lambda at specific river miles, including RM 15, RM 61 at the Little Colorado River confluence, RM 156 at the Havasu Creek confluence, and RM 281 at Pearce Ferry, which can help assess the potential impacts of different management alternatives on smallmouth bass populations. Lambda indicates whether the population is increasing (values greater than 1) or declining (values less than 1). It serves as an important metric for evaluating the reproduction and survival success of smallmouth bass downstream of Glen Canyon Dam. A lambda threshold of less than 1 was chosen for the analysis.

The smallmouth bass model estimates the number of fish that become entrained and survive passage through the dam to determine how dam operations and environmental conditions might influence smallmouth bass population dynamics. When entrainment rates are relatively high (mean estimate of greater than or equal to 100 adult smallmouth bass per year), controlling the invasion

could be challenging due to continued propagule pressure (Eppehimer et al. 2025). However, lower entrainment rates could be a management concern during the early stages of the invasion, as is the case in the Colorado River below Glen Canyon Dam. The mean estimated abundance of adult smallmouth bass in the Glen Canyon Dam tailwater in 2022 and 2023 ranged from approximately 40-50 individuals, with 50 percent credible intervals ranging from approximately 25-55 individuals (Eppehimer et al. 2025). Propagule pressure from reservoirs is an important consideration for smallmouth bass population and invasion dynamics. In the Yampa and Green Rivers of the Upper Colorado River Basin (Breton et al. 2015), 2003–2009 mean estimates of propagule pressure from Elkhead Reservoir into the Yampa River by tagged, translocated smallmouth bass ranged from 21 to 522 individuals per year (Breton et al. 2013). Assuming a theoretical, constant reservoir elevation throughout a year, Lake Powell elevations of 3,536 feet and 3,520 feet correspond to estimated mean annual entrainment and survival rates of approximately 50 and 100 adult smallmouth bass, respectively (Eppehimer et al. 2025; Eppehimer and Yackulic 2026). Therefore, an estimated entrainment rate of greater than or equal to 50 adult smallmouth bass per year could represent more than a doubling of the population of reproductively capable fish. Entrainment of less than 50 individuals was chosen as the analysis threshold below for alternative comparison rather than a desirable condition.

River Flows

River flows for each alternative are reported under **TA 3**, Hydrologic Resources, and are referenced as appropriate within this issue analysis as a baseline for flow conditions that may impact water quality and quantity as they relate to native fish, trout species, and smallmouth bass.

Since 1996, Reclamation has conducted high-flow experiment (HFE) releases from Glen Canyon Dam to manage sediment and maintain or increase sandbar size. These releases are much larger than typical base flows and are specifically designed to enhance sediment deposition. HFE releases are the only current method for generating river stages high enough to build significant sandbars. While HFEs can be as low as 31,500 cubic feet per second, flows of 37,000 cubic feet per second or higher are needed for effective sandbar formation. Most HFEs are of relatively short duration and do not use enough water to significantly impact Lake Powell's elevation or long-term flow conditions. HFEs are primarily sediment management tools and have no direct effect on fish populations in Lake Powell. The only notable biological impact is on fish in the Grand Canyon, especially in the Lees Ferry sub-reach, due to the use of both penstocks and river outlet works that release colder water during HFEs. Please refer to **TA 5**, Geomorphology and Sediment Resources, for a description and analysis of the effects of HFEs downstream of Glen Canyon Dam.

Water Quality

Dissolved oxygen is a critical factor for fish health. Research on dissolved oxygen thresholds for both warmwater and cold-water fish species shows that salmonids are particularly vulnerable to mortality when exposed to low dissolved oxygen concentrations compared to warmwater species (Saari et al. 2017). Sustained dissolved oxygen levels below 3 milligrams per liter (mg/L) can significantly reduce survival rates and feeding efficiency, whereas concentrations in the range of 6–9 mg/L are considered optimal for growth and survival across all life stages (EPA 1986).

Analysis of minimum annual dissolved oxygen concentrations released from Glen Canyon Dam (**Figure TA 6-11**, in **TA 6,** Water Quality) shows that, in the Average Flow Category, all management alternatives result in median dissolved oxygen levels between 4 and 7 mg/L. As flow categories become drier (10.0–12.0 maf) the median dissolved oxygen concentrations decrease and interquartile ranges increase, with more variability among alternatives. In the Critically Dry Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives generally result in lower minimum annual dissolved oxygen concentrations than other alternatives because they are more effective at maintaining elevations above 3,490 feet (see **Figure TA 3-6**, in **TA 3** Hydrologic Resources, and **Figure TA 15-9**, in **TA 15**, Dams and Electrical Power Resources). The remaining alternatives tend to result in elevations below 3,490 feet in the Critically Dry Category, meaning water is released from the river outlet works and modeled dissolved oxygen increases to 8 mg/L. The robustness and vulnerability analyses in this technical appendix evaluate the ability of each alternative to maintain preferred minimum dissolved oxygen concentrations and keep Lake Powell elevation above 3,490 feet.

Robustness analysis (see **Figure TA 6-12** in **TA 6.2.4**, Issue 3) demonstrates that the Enhanced Coordination and Maximum Operational Flexibility Alternatives have the highest percentage of futures in which minimum annual dissolved oxygen concentrations exceed the hypoxic threshold of 2 mg/L in at least 90 percent of years across the full modeling period. In contrast, the CCS Comparative Baseline and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) have the fewest futures that meet this criterion. When considering operational constraints—specifically, Lake Powell elevations below 3,490 feet and the use of river outlet works (with a conservative minimum dissolved oxygen assumption of 8 mg/L)—the Enhanced Coordination and Maximum Operational Flexibility Alternatives remain the most robust (see **Figure TA 6-13** in **TA 6.2.4**, Issue 3). These alternatives are the only ones to maintain dissolved oxygen concentrations above 2 mg/L in at least 90 percent of years in a majority of futures. Similar alternative rankings occur at higher thresholds (e.g., greater than 5 mg/L) with reduced probabilities.

Vulnerability analysis (see **Figure TA 6-14** in **TA 6.2.4**, Issue 3) indicates that the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are reasonably likely to result in undesirable performance (dissolved oxygen below 2 mg/L or Lake Powell below 3,490 feet) because they are vulnerable under hydrologic conditions that have occurred historically and in about 75 percent of traces in the Drying with Variability ensemble, which represents how hydrology could change in a drier future. By contrast, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are reasonably unlikely to result in undesirable performance because they are vulnerable under much drier conditions, which have not been observed historically and occur in only about 10 percent of the Drying with Variability ensemble. The Representative Preferred Alternative is reasonably likely to result in undesirable performance because it is vulnerable under hydrologic conditions that have occurred historically and in about 75 percent of traces in the Drying with Variability ensemble.

While all alternatives perform similarly under wet conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are more resilient to low dissolved oxygen and reservoir elevations during droughts. The general performance comparisons across alternatives would hold true at higher thresholds required to maintain fish health.

Water Temperature

Water temperature conditions relevant to native fish habitat were evaluated using historical temperature records and scenario analysis outputs. Hourly water temperature data were obtained from the GCMRC GCDAMP database for two monitoring stations: Colorado River above the Little Colorado River (USGS station 09383100) and Colorado River above Diamond Creek (USGS station 09404200). The analysis used data from water years 2008–2025.

Hourly temperature records were aggregated to daily mean temperatures. For each water year, the number of days with mean daily temperature exceeding biologically relevant thresholds of 12°C (53.6 °F) and 16 °C (60.8 °F) was calculated. Temperature data from the station above the Little Colorado River were used to evaluate the 12 °C (53.6 °F) threshold, while data from the station above Diamond Creek were used to evaluate the 16 °C (60.8 °F) threshold. These thresholds represent temperature conditions associated with suitable growth and habitat use for humpback chub and other native fishes.

The two locations were selected to reflect differences in spawning and habitat use along the river. Humpback chub populations near the Little Colorado River primarily rely on the tributary for spawning; therefore, the 12 °C (53.6 °F) threshold evaluated at this location reflects conditions supporting growth and seasonal habitat suitability in the mainstream river near the confluence. In contrast, Diamond Creek was used to evaluate the 16 °C (60.8 °F) threshold because it is more representative of warmer mainstream conditions downstream, where humpback chub spawning has been observed. For each year in the analysis period, the total number of days exceeding each temperature threshold was tabulated to characterize the duration of thermally suitable conditions.

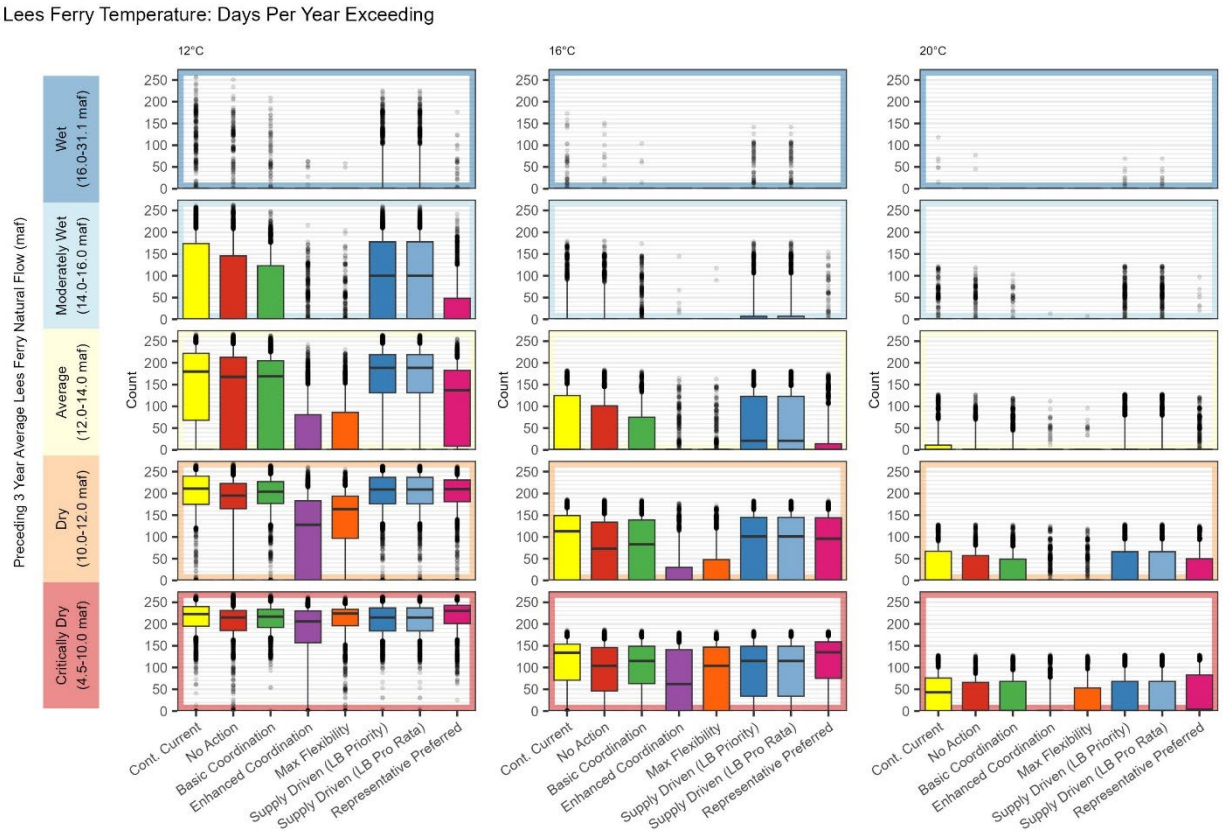
Historical exceedance patterns were used to establish a representative temperature-duration benchmark for subsequent decision-scaling and scenario analyses. Examination of the Diamond Creek record showed that approximately 90 percent of years (16 of 18 water years from 2008–2025) experienced at least 110 days with mean daily temperatures above 16 °C (60.8 °F). Based on this historical relationship, a criterion of at least 110 days above the selected temperature threshold, occurring in at least 90 percent of years, was adopted as a benchmark for sustained thermally suitable conditions.

This benchmark was then applied within the DMDU framework to evaluate projected temperature outcomes under alternative management and hydrologic scenarios. Model outputs were summarized using heatmaps showing the frequency with which the temperature-duration criteria were achieved across scenarios at multiple river locations, including the Colorado River above the Little Colorado River, Havasu Creek, and Pearce Ferry. These analyses were used to evaluate the robustness of management alternatives and to identify hydrologic conditions associated with achieving biologically meaningful temperature targets. This approach highlights longitudinal warming patterns as the river flows downstream from Glen Canyon Dam and provides a basis for comparing projected temperature outcomes across assessed futures. By displaying results in this format, we can evaluate how Lake Powell water temperatures, dam operations, and hydrology may influence thermal regimes.

Lees Ferry

Figure TA 8-9 shows the number of days that modeled water temperatures at Lees Ferry exceed thresholds of 12 °C (53.6 °F), 16 °C (60.8 °F), and 20 °C (68 °F) under each alternative. Exceeding 12 °C (53.6 °F) improves humpback chub growth rates and is considered a desirable response, whereas exceeding 16 °C (60.8 °F) promotes smallmouth bass reproduction and exceeding 20 °C (68 °F) reduces rainbow trout survival; both are considered undesirable responses. Because humpback chub do not typically inhabit the Lees Ferry sub-reach, 12 °C (53.6 °F) is not critical in this analysis but is retained for consistency with subsequent analysis. Thus, fewer days above 16 °C (60.8 °F) would help to limit smallmouth bass spawning without limiting humpback chub. Results are evaluated based on the preceding 3-year average natural flow at Lees Ferry, and the boxplots show the distribution of exceedance days across alternatives and flow regimes.

Figure TA 8-9
Water Temperature at Lees Ferry Based on 3-year Preceding Average River Temperatures at Lees Ferry Exceeding 12° C, 16 °C, and 20 °C Under Each Alternative



For the 12 °C (53.6 °F) threshold, in the Average Flow Category, the No Action and Basic Coordination Alternatives have similar 25th to 75th percentiles, spanning from 0 to just over 200 days, with similar medians of 168 and 169 days, respectively. The CCS Comparative Baseline has a higher median (180 days), with similar 25th–75th percentiles (68–222 days). The Enhanced Coordination and Maximum Operational Flexibility Alternatives exceed 12 °C (53.6 °F) less frequently than the other alternatives and the CCS Comparative Baseline, with 25th–75th percentiles

from 0 days up to 81 and 86 days, respectively. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the highest median (188 days) and a narrower interquartile range (25th and 75th percentiles of 131 and 219 days) than the other alternatives and the CCS Comparative Baseline.

As hydrologic conditions become drier (10.0–12.0 maf and 4.5–10.0 maf), patterns remain similar to those observed in the Average Flow Category, with higher medians and smaller interquartile ranges across alternatives. Under the driest conditions (4.5–10.0 maf), temperatures exceed 12 °C (53.6 °F) more frequently across all alternatives, with the Enhanced Coordination Alternative showing the greatest interquartile range (25th and 75th percentiles of 157 and 230 days).

For the 16 °C (60.8 °F) threshold in the Average Flow Category, the median number of days exceeding 16 °C is 0 days across all alternatives except for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). At these flows, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have about 90 percent of years with 0 days above 16 °C (60.8 °F). As hydrologic conditions become drier, the overall pattern remains similar, although the median number of days exceeding 16 °C (60.8 °F) increases among all alternatives and the CCS Comparative Baseline.

For the 20 °C (68 °F) threshold, variability remains generally similar across alternatives. Under Moderately Wet and Wet Flow Categories, all alternatives and the CCS Comparative Baseline result in 90 percent or more years with zero days exceeding 20 °C (68 °F). Under Dry and Critically Dry Flow Categories, the percentage of years with days exceeding 20 °C (68 °F) marginally increases, but is less than 50 percent of years for all alternatives except the CCS Comparative Baseline in the Critically Dry Flow Category.

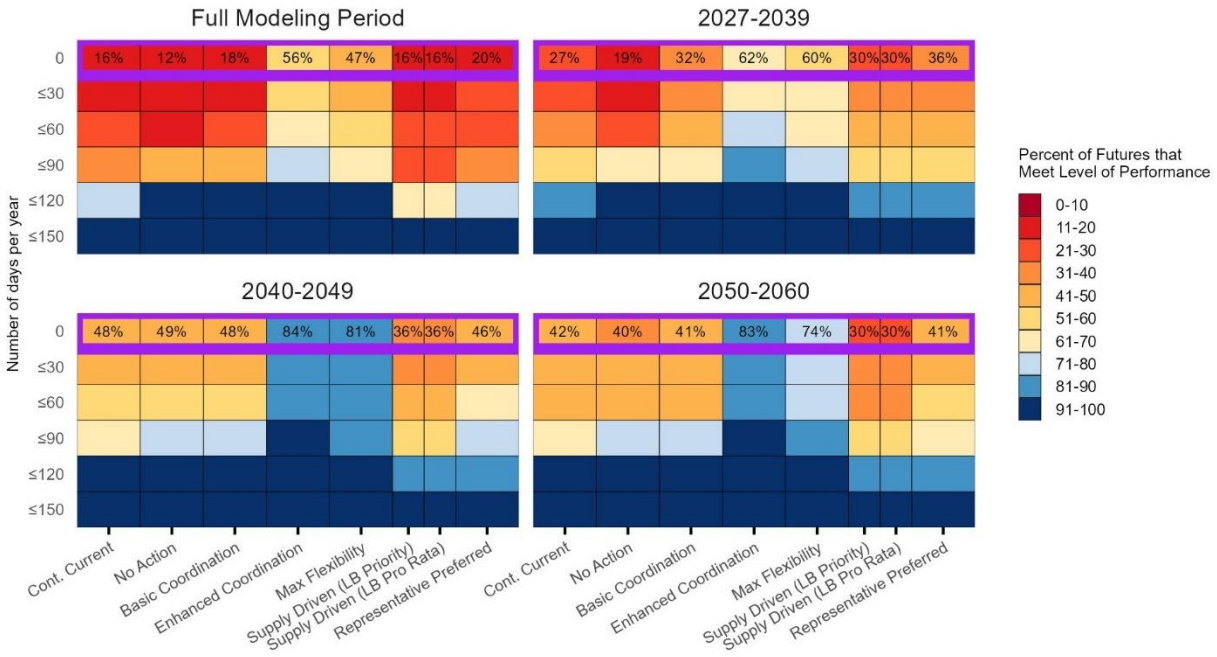
The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 181–231 days with a median of 210 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (0–144 days), with a lower median of 96 days. At 20 °C (68 °F), the median is 0 days with a 75th percentile of only 50 days. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 201–243 days with a median of 230 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (75–159 days), with a lower median of 135 days. At 20 °C (68 °F), the median is 3 days with a 25th and 75th percentile range of 0–83 days.

Overall, as hydrologic conditions become drier, the number of days exceeding each temperature threshold generally increases across alternatives.

Each alternative was evaluated based on its ability to prevent temperatures at Lees Ferry from exceeding 20 °C (68 °F). According to the life histories of rainbow trout and native Grand Canyon fishes, temperatures above 20 °C (68 °F) are likely to decrease rainbow trout survival while creating conditions more favorable for the growth of native fish and smallmouth bass. Additionally, warmer water temperatures may increase brown trout's competitive advantage, as this species is more tolerant of elevated temperatures.

In **Figure TA 8-10**, the percentage of modeled futures for each alternative in which water temperatures remain below 20 °C (68 °F) is evaluated according to the number of days specified by each row. The highlighted row identifies the preferred minimum performance level: that water temperatures remain below 20 °C (68 °F) on all days during the analysis period. Maintaining temperatures below this threshold reduces the risk of rainbow trout mortality due to thermal exposure.

Figure TA 8-10
Rainbow Trout and Native Grand Canyon Fishes Survival: Robustness. Percentage of futures in which the number of days exceeding 20 °C at Lees Ferry is less than the number of days specified by each row



Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at maintaining water temperatures that reduce thermal stress on rainbow trout. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Rows toward the top of the figure represent conditions that allow fewer days below 20 °C (68 °F) and are more difficult to achieve, while rows toward the bottom represent conditions that allow more days above 20 °C (68 °F) and are easier to achieve.

Over the full modeling period, the Enhanced Coordination Alternative is the most robust, meeting the preferred minimum performance level in 56 percent of futures. The Maximum Operational Flexibility Alternative performs lower than the Enhanced Coordination Alternative at 47 percent but still performs substantially better than the remaining alternatives. The No Action and Supply Driven Alternatives, including both the LB Priority and LB Pro Rata approaches, perform similarly and are the least robust, meeting the preferred minimum performance level in 12 to 18 percent of futures and performing similarly to the CCS Comparative Baseline. Decadal comparisons of robustness reveal similar rankings among the alternatives. Robustness scores tend to be lowest in 2027 due to

the low initial reservoir conditions in 2027. Robustness is highest after 2040, with the best-performing alternatives—the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative—nearing or exceeding 80 percent in meeting the preferred minimum performance threshold.

The Representative Preferred Alternative meets the preferred minimum performance level in 20 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination (62 percent) and Maximum Operational Flexibility (60 percent) Alternatives are the most robust. The remaining action alternatives (including the Representative Preferred Alternative) and the CCS Comparative Baseline are similarly less robust (27-36 percent). The No Action Alternative is the least robust (19 percent).

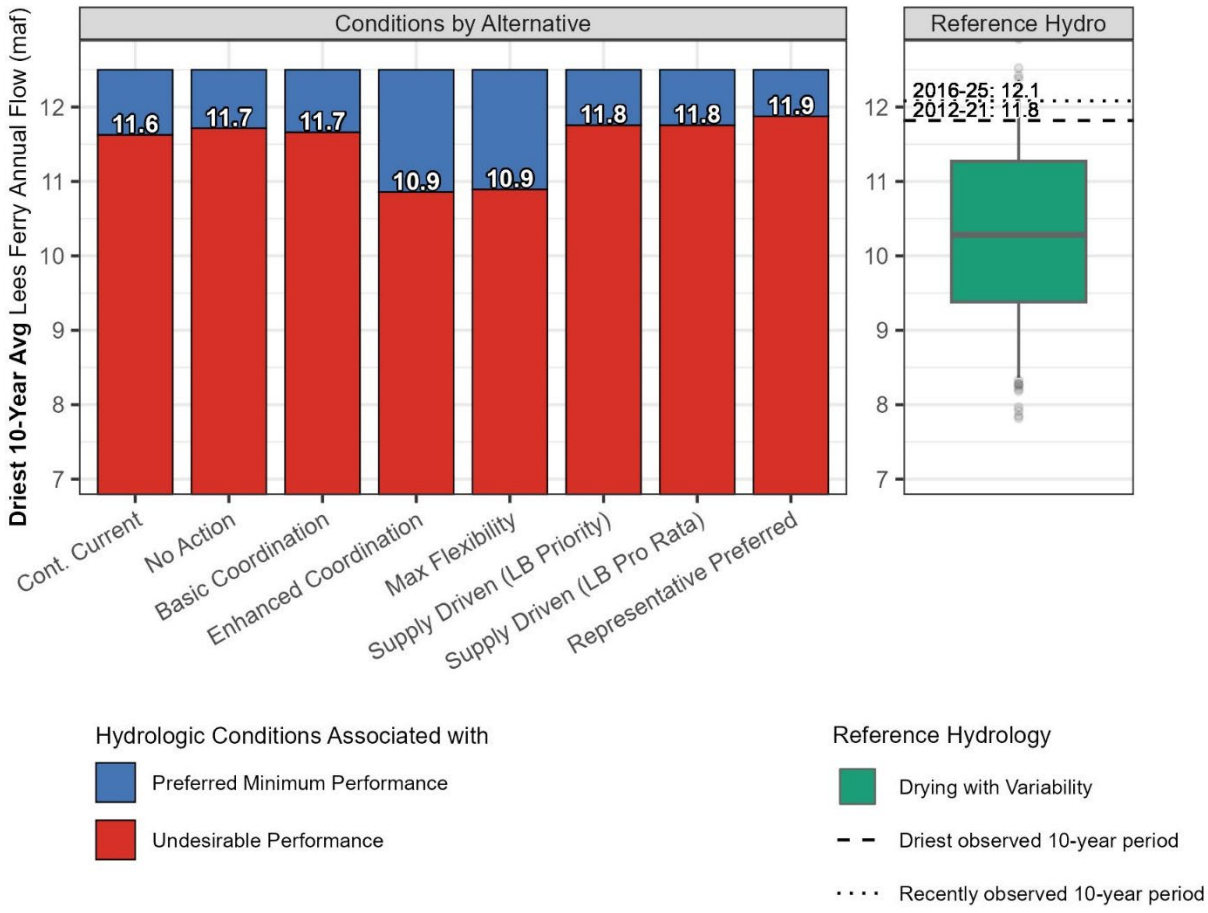
Figure TA 8-11 below shows what flow conditions are likely to result in at least one day with temperature at Lees Ferry exceeding 20 °C (68 °F). This definition of undesirable performance is based on the highlighted row in **Figure TA 8-10** above, which defined a future as successful when an alternative always maintained temperatures below 20 °C (68 °F).

The driest 10-year average Lees Ferry natural flow was identified as a skillful predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented in the Drying with Variability ensemble, which represents how hydrology could change in a drier future. The most recent and driest observed historical 10-year periods are also shown as dotted and dashed lines. The Drying with Variability ensemble's median value is approximately 10.3 maf. The most recent 10-year average Lees Ferry annual flow is 12.1 maf (2016–2025), and the driest 10-year period in the observed record is 11.8 maf (2012–2021).

The CCS Comparative Baseline and No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to temperatures exceeding 20 °C (68 °F) under similar conditions: 10-year average flows between 11.6 and 11.8 maf or lower. These alternatives are reasonably likely to result in undesirable performance because flows similar to this have occurred in the past, and about 90 percent of traces in the Drying with Variability ensemble exhibit these conditions. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are less vulnerable, becoming susceptible to undesirable performance under flows of 10.9 maf. Although these conditions have not occurred historically, about 75 percent of traces in the Drying with Variability ensemble exhibit these conditions

Overall, the Enhanced Coordination Alternative is the most robust for maintaining cooler temperatures at Lees Ferry, followed closely by the Maximum Operational Flexibility Alternative. Cooler conditions support rainbow trout survival and limit smallmouth bass reproduction, but may constrain the growth of some native fishes. Alternatives that maintain higher Lake Powell elevations and cooler release temperatures generally perform better than the No Action Alternative and CCS Comparative Baseline. However, during extended droughts, all alternatives become more vulnerable to warming, which can alter fish habitat and species composition by increasing the presence of native fish and smallmouth bass and potentially favoring brown trout over rainbow trout.

Figure TA 8-11
Rainbow Trout and Native Grand Canyon Fishes Survival: Vulnerability. Conditions that could cause the temperature at Lees Ferry to exceed 20°C in one or more days

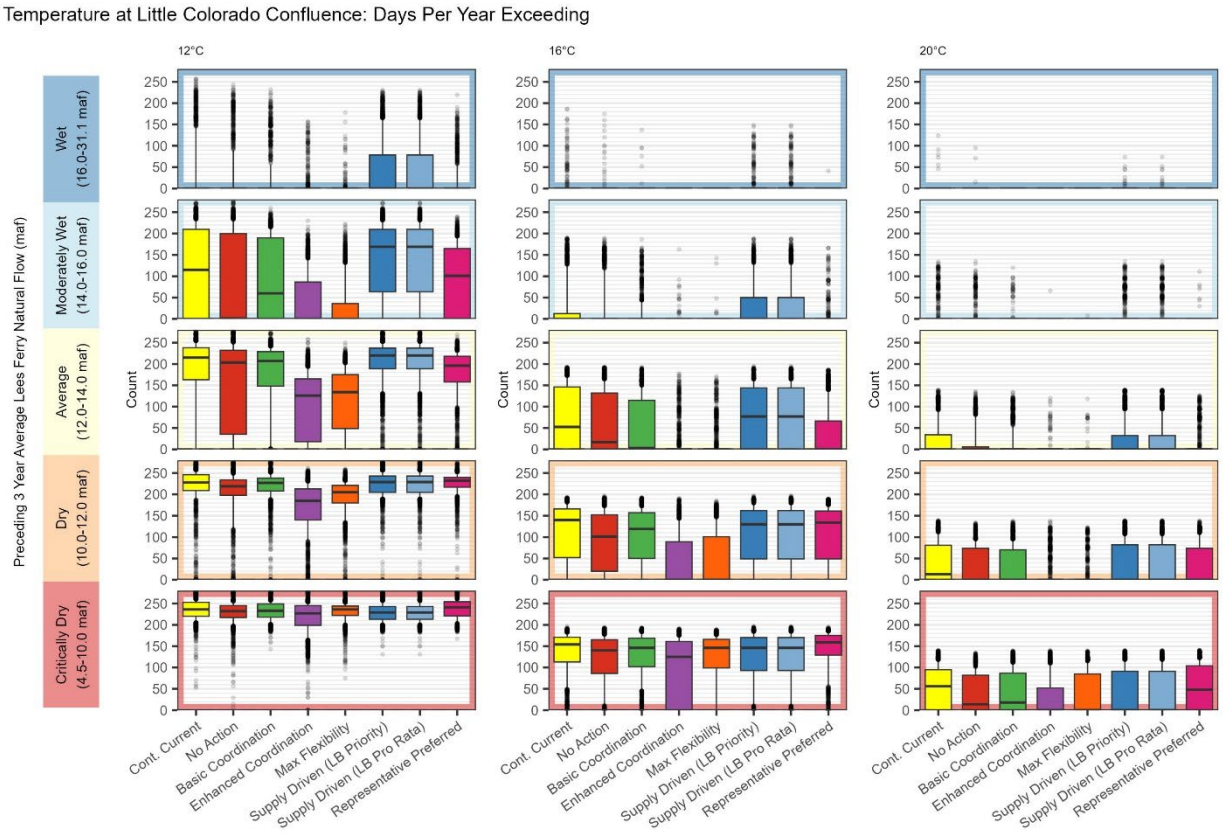


The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 11.9 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has occurred before. Compared to the Drying with Variability ensemble that represents potential future hydrologic conditions, approximately 90 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Little Colorado River Confluence

Figure TA 8-12 shows the number of days that modeled water temperatures at the Little Colorado River confluence exceed thresholds of 12 °C (53.6 °F), 16 °C (60.8 °F), and 20 °C (68 °F) under each alternative. Results are evaluated based on the preceding 3-year average natural flow at Lees Ferry, and the boxplots show the distribution of exceedance days across alternatives and flow regimes.

Figure TA 8-12
Water Temperature at the Little Colorado River Confluence Based on 3-year Preceding Average River Temperatures at Lees Ferry Exceeding 12 °C, 16 °C, and 20 °C Under Each Alternative



For the 12 °C (53.6 °F) threshold in the Average Flow Category, the Basic Coordination Alternative and CCS Comparative Baseline have similar 25th to 75th percentiles spanning from 148 to approximately 238 days, but different medians (207 and 215 days, respectively). The No Action Alternative has a median similar to those of the Basic Coordination Alternative and the CCS Comparative Baseline, but with greater variability (25th and 75th percentiles of 36 and 232 days). The Enhanced Coordination and Maximum Operational Flexibility Alternatives exceed 12 °C (53.6 °F) less frequently than the other alternatives and the CCS Comparative Baseline, with 25th and 75th percentiles of 18 and 165 days and 49 and 175 days, respectively. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has a higher median (220 days) and a narrower interquartile range (25th and 75th percentiles of 189 and 237 days) compared to the other alternatives and the CCS Comparative Baseline.

In the Dry and Critically Dry Flow Categories, the median number of days above 12 °C (53.6 °F) tends to increase while variability decreases. Comparisons between alternatives remain similar to those observed in the Average Flow Category. In the Critically Dry Flow Category, temperatures exceed 12 °C (53.6 °F) with higher frequency across all alternatives, with the Enhanced

Coordination Alternative showing the most variability (25th and 75th percentiles of 199 and 245 days).

For the 16 °C (60.8 °F) threshold, the median number of days exceeding 16 °C (60.8 °F) is considerably lower than the 12 °C (53.6 °F) threshold, and even 0 days for the Enhanced Coordination and Maximum Operational Flexibility Alternatives in all but the Critically Dry Flow Category. In Wet to Dry Flow Categories, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have relatively few years with days above 16 °C (60.8 °F). As hydrologic conditions become drier, the overall pattern remains similar, although the median number of days exceeding 16 °C (60.8 °F) increases among all alternatives and the CCS Comparative Baseline.

For the 20 °C (68 °F) threshold, under Wet to Average Flow Categories, there are few years with days exceeding 20 °C (68 °F). The percentage of years exceeding 20 °C (68 °F) increases for all alternatives in the Dry and Critically Dry Flow Categories.

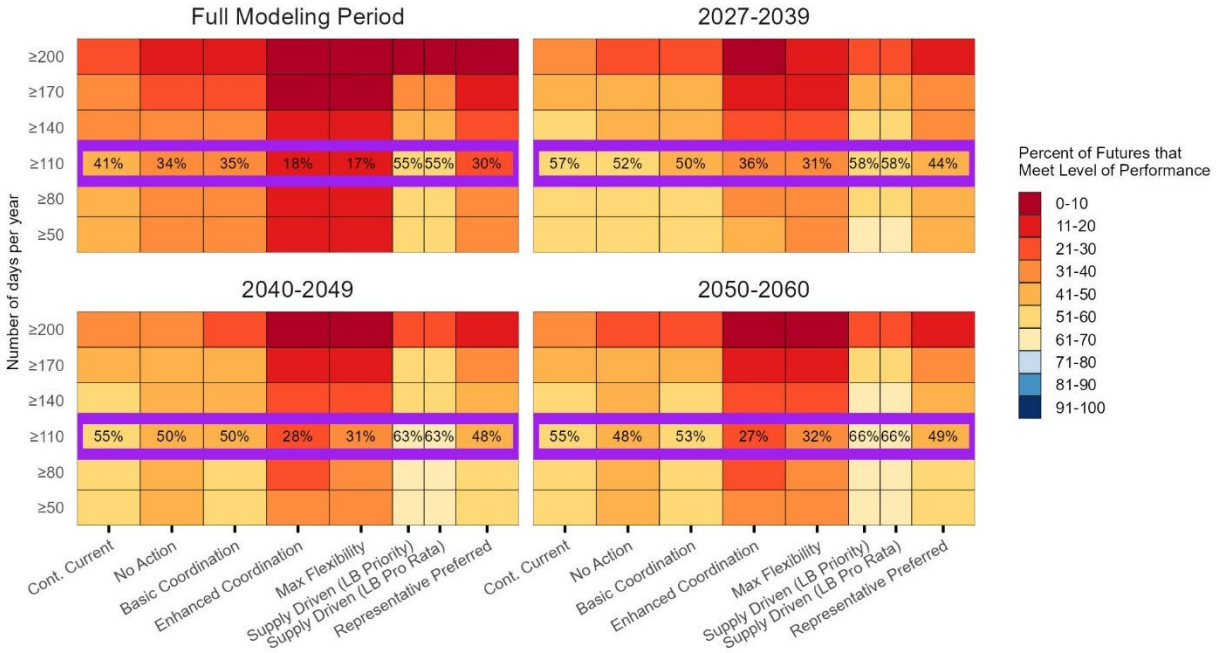
The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 217–240 days with a median of 232 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (49–161 days), with a lower median of 134 days. At 20 °C (68 °F), the median is 0 days with a 75th percentile of only 74 days. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 221–254 days with a median of 241 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (129–175 days), with a lower median of 159 days. At 20 °C (68 °F), the median is 48 days with a 25th and 75th percentile range of 0–104 days.

Overall, as hydrologic conditions become drier, the number of days exceeding each temperature threshold generally increases. Enhanced Coordination and Maximum Operational Flexibility tend to result in fewer days above the temperature thresholds than the other alternatives, and the differences among the other alternatives is relatively small.

Each alternative was analyzed based on the number of days per year water temperatures exceed 12 °C (53.6 °F) and 16 °C (60.8 °F). Based on native Grand Canyon fishes' and smallmouth bass life histories, temperatures above 12 °C (53.6 °F) would be conducive to humpback chub growth. Water temperatures exceeding 16 °C (60.8 °F) promote spawning in humpback chub and smallmouth bass. Although warmer water temperatures are beneficial to native fish, such as humpback chub, maintaining cooler water temperatures may limit smallmouth population growth within critical humpback chub habitats.

Figure TA 8-13 reports the percent of modeled futures in which water temperatures at the Little Colorado River confluence exceed 12 °C (53.6 °F) in the number of days per year specified by each row, in at least 90 percent or more of the years. The highlighted row identifies the preferred minimum performance level: that water temperatures exceed 12 °C (53.6 °F) for at least 110 days per year, in at least 90 percent of years. This threshold was selected based on a historical analysis that found that during water years 2008–2025, all but one year had at least 110 days with average daily temperatures above 12 °C (53.6 °F) at the Little Colorado River confluence.

Figure TA 8-13
Humpback Chub Growth at the Little Colorado River Confluence: Robustness. Percentage of modeled futures in which water temperature at the Little Colorado River confluence exceeds 12 °C for at least the number of days per year specified in each row in 90 percent or more of years.



Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at providing water temperatures that promote humpback chub growth. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which temperatures exceed 12 °C (53.6 °F) for a greater number of days and are more difficult to achieve, while lower rows represent fewer days above 12 °C (53.6 °F) and are easier to achieve.

Over the full modeling period, the Basic Coordination Alternative performs similarly to the No Action Alternative and the CCS Comparative Baseline, meeting the preferred minimum performance level in 34 to 41 percent of futures. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform substantially worse, only meeting the preferred minimum performance level in 18 percent and 17 percent of futures, respectively. The best-performing alternatives (Supply Driven [LB Priority and LB Pro Rata]) are substantially more robust than the Enhanced Coordination and Maximum Flexibility Alternatives, and to a lesser degree, more robust than the Basic Coordination and No Action Alternatives, as well as the CCS Comparative Baseline. As the number of days increases (higher rows in the figure), robustness declines across all alternatives. The same pattern is revealed with the decadal breakout of robustness. Years that maintain higher Lake Powell elevations and greater flow from Glen Canyon Dam create conditions that allow for cooler water temperatures at the Little Colorado River confluence. Overall, alternatives that limit the number of days exceeding 12 °C (53.6 °F), particularly the Enhanced

Coordination and Maximum Operational Flexibility Alternatives, reduce the likelihood of thermal conditions that support humpback chub growth.

The Representative Preferred Alternative meets the preferred minimum performance level in 30 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are similar and the most robust, meeting the preferred minimum performance 50-58 percent of futures. The Representative Preferred Alternative is in the middle (44 percent), and the Enhanced Coordination (36 percent) and Maximum Operational Flexibility (31 percent) Alternatives are the least robust.

Figure TA 8-14 reports the percentage of modeled futures in which water temperatures at the Little Colorado River confluence exceed 16 °C (60.8 °F) in the number of days per year specified by each row, in at least 90 percent or more of the years. The highlighted row identifies the preferred minimum performance level: water temperatures exceeding 16 °C (60.8 °F) for greater than 110 days in at least 90 percent of years during the analysis period. This threshold was selected based on a historical analysis that found that during water years 2008–2025, all but one year had at least 110 days with average daily temperatures above 16 °C (60.8 °F) at the Diamond Creek Confluence. Temperatures at Diamond Creek were used to inform the threshold in this analysis of temperatures at the Little Colorado River confluence because of known humpback chub mainstream spawning throughout the western Grand Canyon.

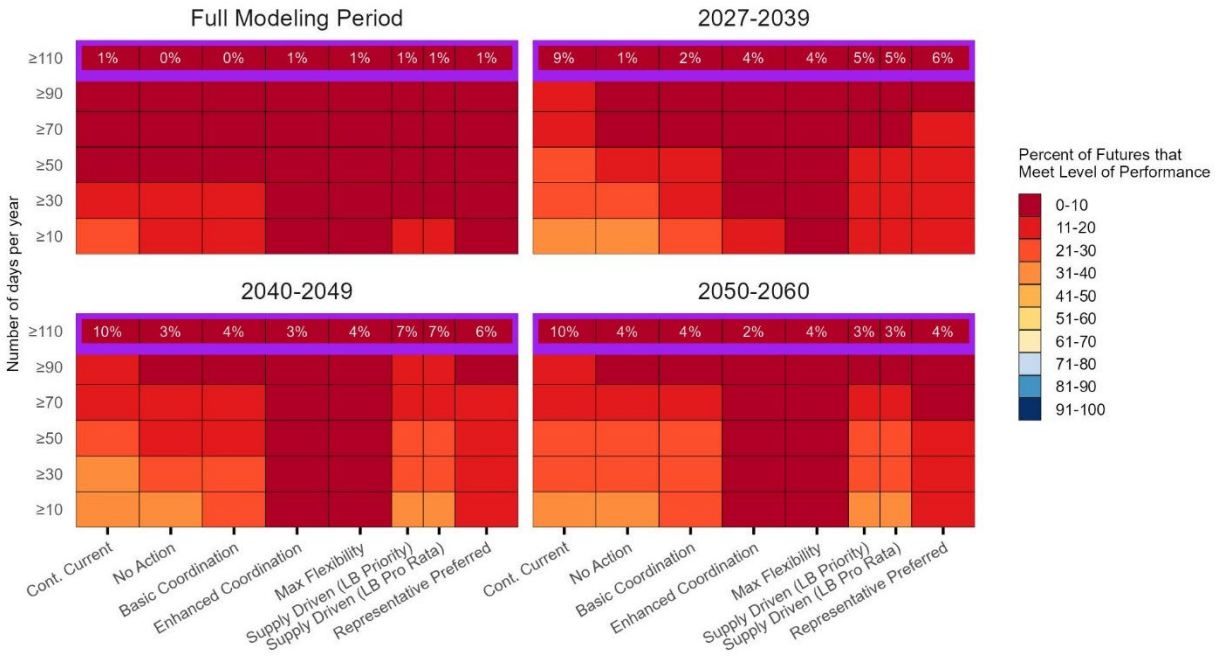
Alternatives that achieve this preferred minimum performance level in a higher percentage of futures better promote humpback chub spawning. Simultaneously, the same conditions could also promote smallmouth bass spawning. Lower rows require fewer days per year above 16 °C (60.8 °F) and are easier to achieve.

Over the full modeling period, all alternatives perform poorly, meeting the preferred minimum performance level in 0 or 1 percent of modeled futures. As the number of days required decreases (lower rows), robustness increases across all alternatives but with relatively low scores. Similar results are observed when broken out by decade.

These results indicate it is difficult to achieve temperatures at the Little Colorado River confluence that support mainstream spawning of humpback chub. However, in this area of the river, humpback chub utilize the Little Colorado River proper for spawning and may not be as dependent on mainstream water temperatures in this area of the Grand Canyon. Although the alternatives perform poorly at promoting humpback chub spawning in the mainstream river, this also indicates poor conditions for smallmouth bass spawning.

The Representative Preferred Alternative meets the preferred minimum performance level in 1 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. All alternatives and the CCS Comparative Baseline perform poorly, meeting the preferred minimum performance in 1-9 percent of futures. The Representative Preferred Alternative meets the preferred minimum performance in 6 percent of futures.

Figure TA 8-14
Humpback Chub Spawning at the Little Colorado River Confluence: Robustness. Percentage of futures in which the temperature at the Little Colorado River confluence exceeds 16 °C in the days per year specified by each row in 90 percent or more of years.

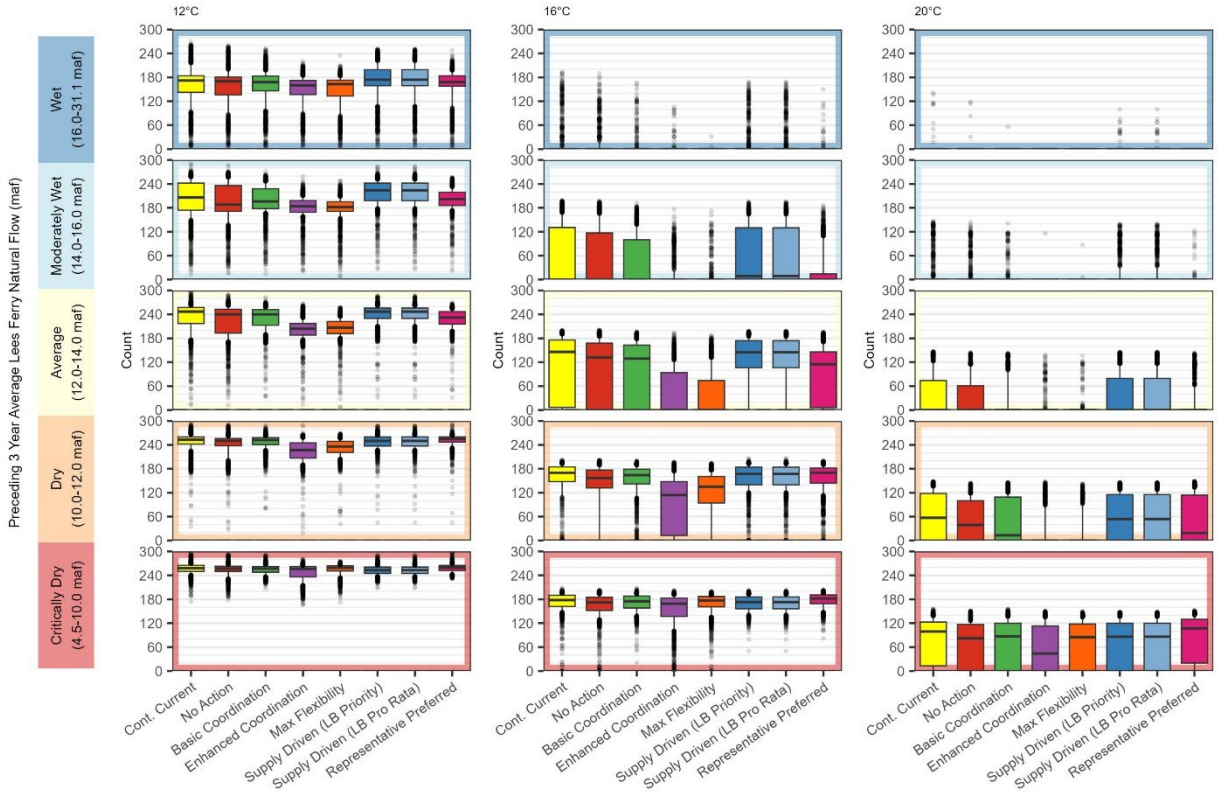


Havasu Creek Confluence

Figure TA 8-15 shows the number of days per year that modeled water temperatures at the Havasu Creek confluence exceed thresholds of 12 °C (53.6 °F), 16 °C (60.8 °F), and 20 °C (68 °F) under each alternative. Results are evaluated based on the preceding 3-year average natural flow at Lees Ferry, and the boxplots show the distribution of exceedance days across alternatives and flow regimes.

For the 12 °C (53.6 °F) threshold, in the Average Flow Category, the Basic Coordination, No Action, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives and the CCS Comparative Baseline result in similar median values, ranging from 240 to 247 days. These alternatives differ in terms of variability and 25th percentiles, with the No Action Alternative having the most variability and the lowest 25th percentile (193 days) and Supply Driven (both LB Priority and LB Pro Rata approaches) being the least variable and having the highest 25th percentile (230 days) among these alternatives. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have notably lower median values of 204 and 207 days, meaning they exceed 12 °C (53.6 °F) less frequently.

Figure TA 8-15
Water Temperature at the Havasu Creek Confluence Based on 3-year Preceding Average River Temperatures at Lees Ferry Exceeding 12 °C, 16 °C, and 20 °C Under Each Alternative



In the Dry and Critically Dry Flow Categories, patterns remain similar to those observed in the Average Flow Category, but with higher medians and smaller interquartile ranges across alternatives. In the Critically Dry Flow Category, temperatures exceed 12 °C (53.6 °F) at similar frequencies across alternatives, although the Enhanced Coordination Alternative shows the largest interquartile range (25th and 75th percentiles of 236 and 262 days).

For the 16 °C (60.8 °F) threshold, variability increases compared to the 12 °C (53.6 °F) results due to a higher frequency of years that result in zero or only a small number of days that exceed 16 °C (60.8 °F). Across all alternatives, median values are lower. In the Average Flow Category, all alternatives except Enhanced Coordination and Maximum Operational Flexibility have similar medians between 129 and 146 days. Enhanced Coordination and Maximum Operational Flexibility tend to have fewer days above 16 °C (60.8 °F), with median values of 0 days. Median values tend to increase, and variability decreases in the Dry and Critically Dry Flow Categories.

For the 20 °C (68 °F) threshold, the frequency of exceeding 20 °C (68 °F) is low in the Wet to Average Flow Categories, demonstrated by all alternatives having median values of 0. The frequency of days above 20 °C (68 °F) increases under drier conditions, with median values ranging from 44

days (Enhanced Coordination Alternative) to 99 days (CCS Comparative Baseline) in the Critically Dry Flow Category. The Enhanced Coordination Alternative has the lowest median value (44 days).

The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 247–260 days with a median of 255 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (144–182 days), with a lower median of 170 days. At 20 °C (68 °F), the median is 19 days with a 25th and 75th percentile range of 0–114 days. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 252–265 days with a median of 260 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (169–191 days), with a lower median of 182 days. At 20 °C (68 °F), the median is 107 days with a 25th and 75th percentile range of 20–130 days.

Overall, as hydrologic conditions become drier, the number of days exceeding each temperature threshold generally increases. Most alternatives are relatively similar except Enhanced Coordination and Maximum Operational Flexibility, which tend to result in fewer days per year exceeding the temperature thresholds.

Figure TA 8-16 reports the percentage of modeled futures in which water temperatures at the Havasu Creek confluence exceed 12 °C (53.6 °F) in the number of days per year specified by each row, in at least 90 percent or more of the years. The highlighted row identifies the preferred minimum performance level: water temperatures exceeding 12 °C (53.6 °F) for at least 110 days in at least 90 percent of years during the analysis period. This threshold was selected based on the computed daily average temperature and the analysis of the number of days per water year (2008–2025) with average daily temperatures above 12 °C (53.6 °F) at the Little Colorado River.

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at providing water temperatures that promote humpback chub growth. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which temperatures exceed 12 °C (53.6 °F) for a greater number of days and are more difficult to achieve, while lower rows represent fewer days above 12 °C (53.6 °F) and are easier to achieve.

Over the full modeling period, all alternatives performed well at the greater than 110-day threshold (87 percent or higher of futures). The Supply Driven Alternative, including both the LB Priority and LB Pro Rata approaches, and the Basic Coordination Alternative, all show robustness greater than or equal to 90 percent of futures. Similar performance is observed in each decade.

The Representative Preferred Alternative meets the preferred minimum performance level in 93 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. All alternatives are robust, meeting the preferred minimum performance in 89-93 percent of futures. Specifically, the Representative Preferred Alternative meets the preferred minimum performance in 93 percent of futures.

Figure TA 8-16
Humpback Chub Growth at the Havasu Creek Confluence: Robustness. Percentage of futures in which the temperature at the Havasu Creek confluence exceeds 12 °C in the days specified by each row in 90 percent or more of years.

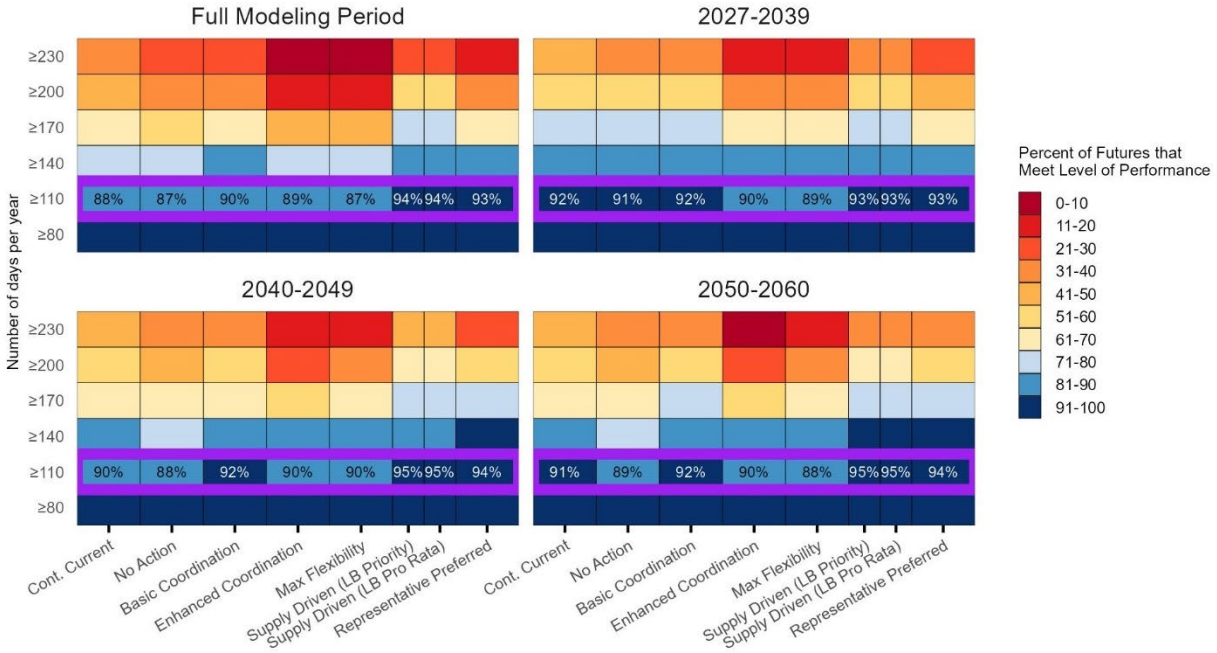
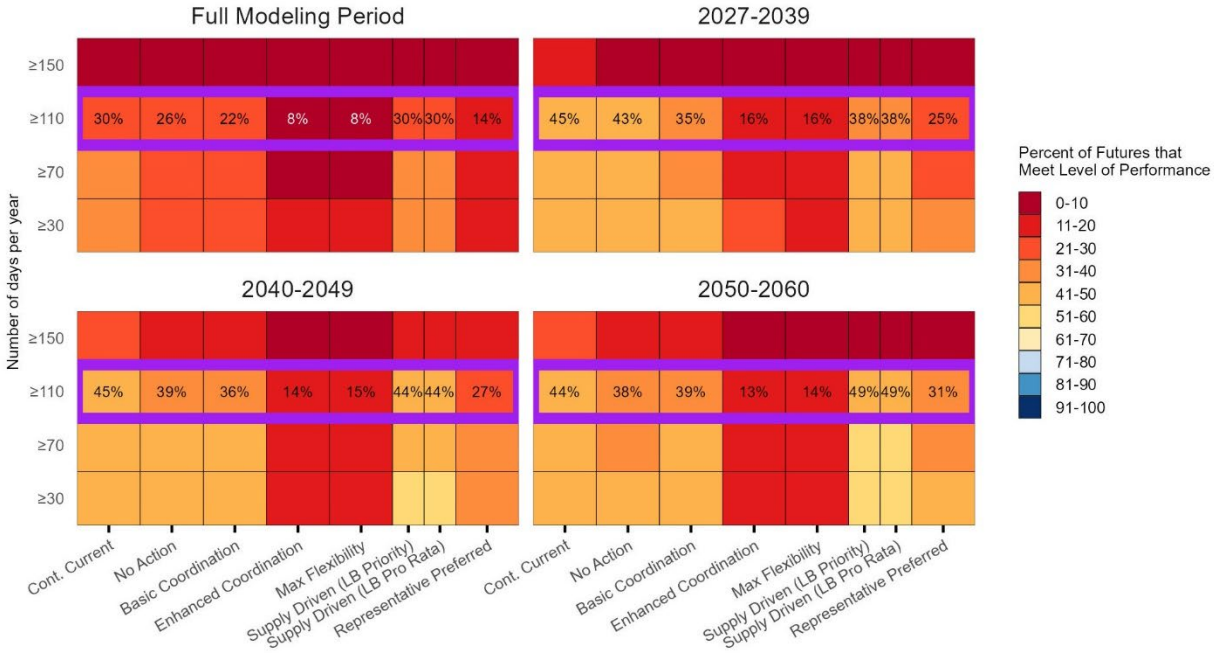


Figure TA 8-17 reports the percentage of modeled futures in which water temperatures at the Havasu Creek confluence exceed 16 °C (60.8 °F) in the number of days per year specified by each row, in at least 90 percent of years. The highlighted row identifies the preferred minimum performance level: water temperatures exceeding 16 °C (60.8 °F) for at least 110 days in at least 90 percent of years during the analysis period. This threshold was selected based on a historical analysis that found that during water years 2008–2025, all but one year had at least 110 days with average daily temperatures above 16 °C (60.8 °F) at the Diamond Creek Confluence. Temperatures at Diamond Creek were used to inform the threshold in this analysis of temperatures at the Havasu Creek Confluence because of known humpback chub mainstream spawning throughout the western Grand Canyon.

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures better promote thermal conditions conducive to humpback chub spawning. Conversely, alternatives that achieve this preferred minimum performance level in a lower percentage of futures are more effective at limiting thermal conditions that support smallmouth bass spawning. Higher rows represent conditions with more days exceeding 16 °C (60.8 °F) and are more difficult to achieve, while lower rows represent fewer days above 16 °C (60.8 °F) and are easier to achieve.

Figure TA 8-17
Humpback Chub Spawning at the Havasu Creek Confluence: Robustness. Percentage of futures in which the temperature at the Havasu Creek confluence exceeds 16 °C in the days specified by each row in 90 percent or more of years.



Over the full modeling period, the Basic Coordination Alternative and the Supply Driven Alternative, including both the LB Priority and LB Pro Rata approaches, perform similarly to the No Action Alternative and the CCS Comparative Baseline, meeting the preferred minimum performance level in 22 to 30 percent of futures. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform worse, only meeting the preferred minimum performance level in 8 percent of futures. Considering the results by decade, the comparison between alternatives remains generally the same, although robustness increases slightly for each alternative. As the required number of days decreases (lower rows in the figure), robustness increases slightly across all alternatives.

Overall, the Enhanced Coordination and Maximum Operational Flexibility Alternatives result in fewer days exceeding 16 °C (60.8 °F) compared to the other alternatives and the CCS Comparative Baseline, which is less conducive to humpback chub spawning. However, Enhanced Coordination and Maximum Operational Flexibility Alternatives result in temperatures less conducive for smallmouth bass spawning.

The Representative Preferred Alternative meets the preferred minimum performance level in 14 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are the most robust, meeting the preferred minimum performance in

35-45 percent of futures. The Representative Preferred Alternative is in the middle (25 percent), and the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust (both 16 percent).

As with the Little Colorado River, exceeding the 12 °C (53.6 °F) threshold creates thermal conditions that support mainstream humpback chub growth. While these warmer temperatures can benefit native humpback chub by enhancing growth and recruitment, temperatures exceeding 16 °C (60.8 °F) also favor smallmouth bass, which may increase predation and competition pressures on native fish populations. The comparative analysis of alternatives at the 12 °C (53.6 °F) and 16 °C (60.8 °F) thresholds is critical for identifying management scenarios that balance the needs of native and nonnative species. Alternatives that limit the number of days above these temperature thresholds (Enhanced Coordination and Maximum Operational Flexibility Alternatives) may help reduce smallmouth bass population growth but could also restrict opportunities for humpback chub reproduction.

Pearce Ferry

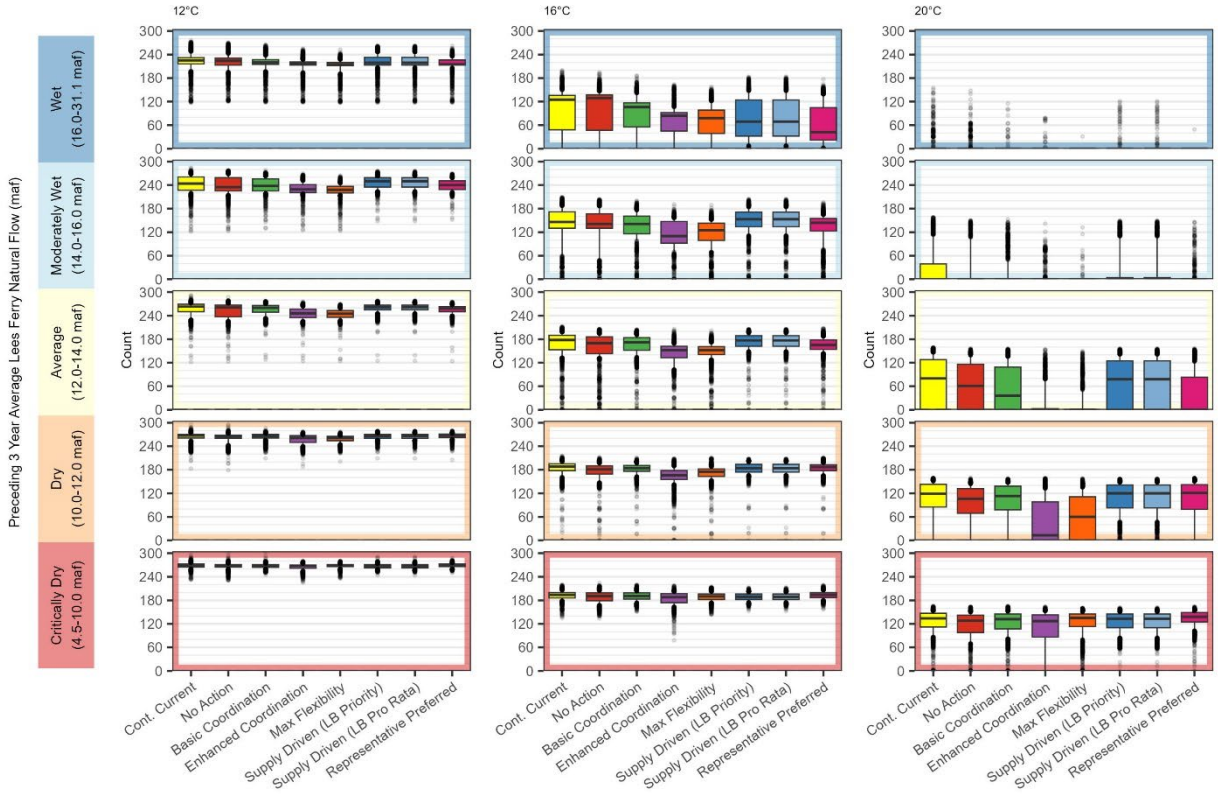
Water temperature analysis at Pearce Ferry allows comparison of variability among alternatives, providing insight into the likelihood of exceeding thresholds that affect humpback chub and smallmouth bass population growth. Although water temperatures at Pearce Ferry can be influenced by Glen Canyon Dam release temperatures, the location is also more influenced by ambient air temperatures relative to upstream reaches. In the fall, when dam releases can be at their warmest, when the lake naturally turns over, and the warmer water is more aligned with the penstock, mainstream water temperatures may cool as they move downstream over 280 river miles. During warmer months, cooler releases from the dam result in cooler water moving downstream (Valdez et al. 2013). This can create a scenario in which average and maximum temperatures are more similar across alternatives at this location.

Figure TA 8-18 shows the number of days that modeled water temperatures at Pearce Ferry exceed thresholds of 12 °C (53.6 °F), 16 °C (60.8 °F), and 20 °C (68 °F) under each alternative. Results are evaluated based on the preceding 3-year average natural flow at Lees Ferry. The boxplots display the range of outcomes for each alternative across different flow regimes. Each row represents a flow category, and the distributions show the number of days temperatures exceed the specified threshold under each alternative.

For the 12 °C (53.6 °F) threshold, in the Average Flow Category, the Enhanced Coordination and Maximum Operational Flexibility Alternatives have lower medians of 246 and 245 days, respectively, while the remaining alternatives and CCS Comparative Baseline have median values between 260 and 263 days. No Action exhibits greater variability, caused by a low 25th percentile of 237 days (similar to Enhanced Coordination and Maximum Operational Flexibility) whereas the other alternatives have 25th percentiles between 249 and 255 days.

In the Dry and Critically Dry Flow Categories, median values increase for all alternatives and variability decreases. Under the Critically Dry Flow Category, median values are similar for all alternatives and the CCS Comparative Baseline, between 267 and 269 days.

Figure TA 8-18
Water Temperature at Pearce Ferry Based on 3-year Preceding Average River Temperatures at Lees Ferry Exceeding 12 °C, 16 °C, and 20 °C Under Each Alternative



For the 16 °C (60.8 °F) threshold, median values are lower and interquartile ranges are larger across all alternatives and the CCS Comparative Baseline under each flow category. As conditions become drier, interquartile ranges tend to decrease among alternatives and the CCS Comparative Baseline.

For the 20 °C (68 °F) threshold, in the Very Wet and Wet Flow Categories, the frequency of exceeding 20 °C (68 °F) is low for all alternatives. However, in the Average, Dry, and Critically Dry Flow Categories, the frequency of exceeding 20 °C (68 °F) increases. In the Critically Dry Flow Category, the median number of days above 20 °C (68 °F) ranges between 127 and 135 days.

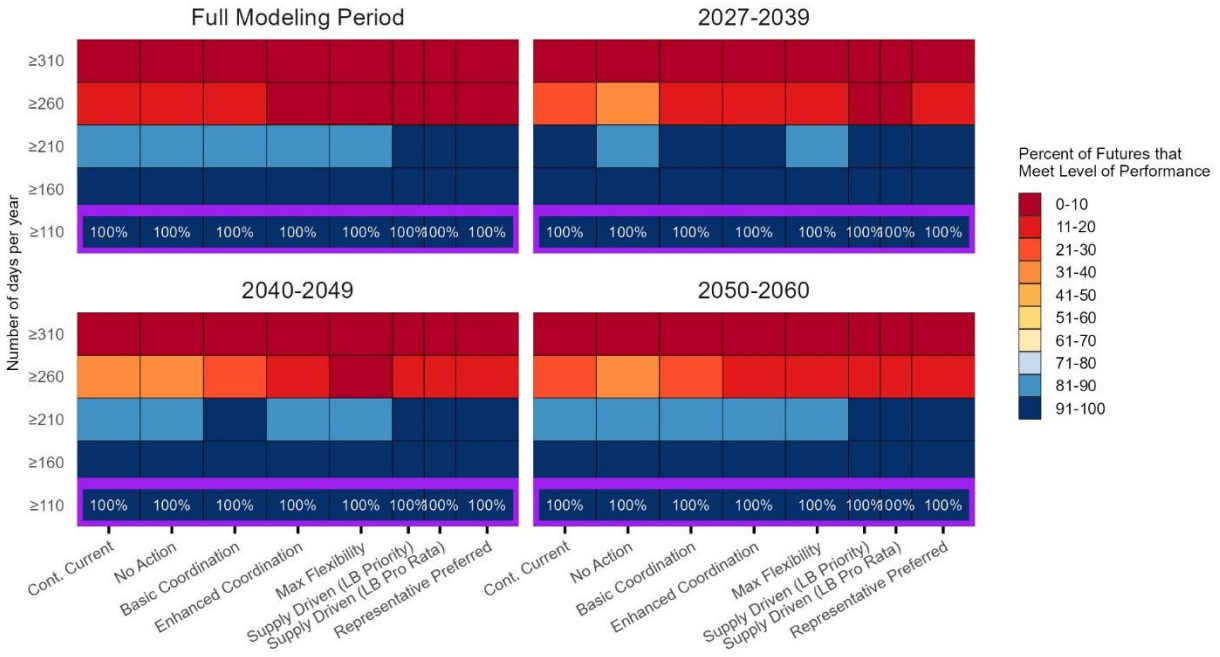
The Representative Preferred Alternative exhibits the following outcomes with respect to the Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 262–271 days with a median of 267 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (178–193 days), with a lower median of 187 days. At 20 °C (68 °F), the median is 121 days with a 25th and 75th percentile range of 79–142 days. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the 12 °C (53.6 °F) threshold, the 25th and 75th percentiles range from 266–273 days with a median of 270 days. At 16 °C (60.8 °F), the number of days decreases between the 25th and 75th percentile (187–200 days), with a lower median of 194 days. At 20 °C (68 °F), the median is 138 days with a 25th and 75th percentile range of 125–149 days.

Overall, as hydrologic conditions become drier, the number of days exceeding each temperature threshold generally increases. The differences between alternatives are relatively small except for the Enhanced Coordination and Maximum Operational Flexibility Alternatives, which can result in fewer days exceeding each temperature threshold.

Figure TA 8-19 reports the percentage of modeled futures in which water temperatures at Pearce Ferry exceed 12 °C (53.6 °F) is in the number of days specified by each row in at least 90 percent of years. The highlighted row identifies the preferred minimum performance level: water temperatures exceeding 12 °C (53.6 °F) for at least 110 days in at least 90 percent of years during the analysis period. This threshold was selected based on the computed daily average temperature and the analysis of the number of days per water year (2008–2025) with average daily temperatures above 12 °C (53.6 °F) at the Little Colorado River.

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at providing water temperatures that promote humpback chub growth. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which temperatures exceed 12 °C (53.6 °F) for a greater number of days and are more difficult to achieve, while lower rows represent fewer days above 12 °C (53.6 °F) and are easier to achieve.

Figure TA 8-19
Humpback Chub Growth at Pearce Ferry: Robustness.
Percentage of futures in which the temperature at Pearce Ferry exceeds 12 °C in the days specified by each row in 90 percent or more of years



Over the full modeling period and within each decade, all alternatives meet the preferred minimum performance (at least 110 days above 12 °C [53.6 °F] in 90 percent or more years) in 100 percent of the analyzed futures. Differences in performance are not revealed until the number of days per year exceeds 210. Alternatives that create higher elevations at Lake Powell and increase flow allow for cooler water temperatures at Pearce Ferry, even though ambient temperature plays an important role in water temperatures there.

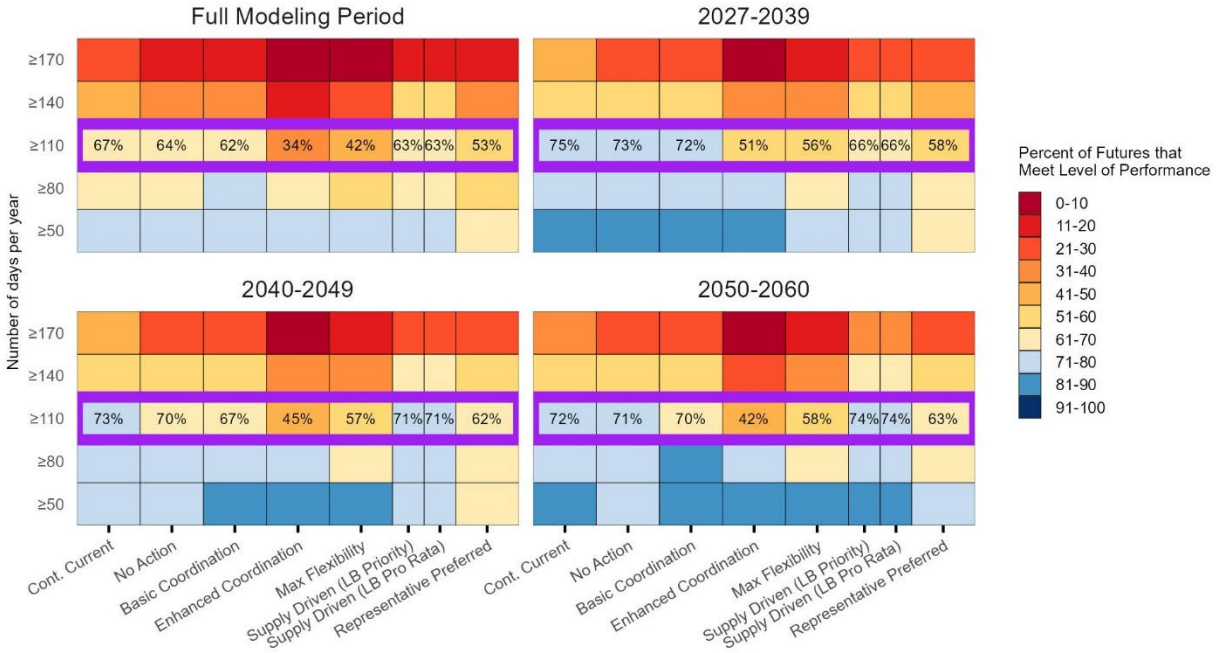
The Representative Preferred Alternative meets the preferred minimum performance level in 100 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to note that it meets the preferred minimum performance level in 100 percent of futures in the first modeling period, as do the other alternatives and the CCS Comparative Baseline.

Figure TA 8-20 reports the percentage of modeled futures in which water temperatures at Pearce Ferry exceed 16 °C (60.8 °F) in the number of days specified by each row in at least 90 percent of years. The highlighted row identifies the preferred minimum performance level: water temperatures exceeding 16 °C (60.8 °F) for more than 110 days in at least 90 percent of years during the analysis period. This threshold was selected based on a historical analysis that found that during water years 2008–2025, all but one year had at least 110 days with average daily temperatures above 16 °C (60.8 °F) at the Diamond Creek Confluence. Temperatures at Diamond Creek were used to inform the threshold in this analysis of temperatures at the Havasu Creek Confluence because of known humpback chub mainstream spawning throughout the western Grand Canyon. Alternatives that achieve this preferred minimum performance level in a higher percentage of futures better promote thermal conditions conducive to humpback chub spawning. Conversely, alternatives that achieve this preferred minimum performance level in a lower percentage of futures are more effective at limiting thermal conditions that support smallmouth bass spawning. Higher rows represent conditions with more days exceeding 16 °C (60.8 °F) and are more difficult to achieve, while lower rows represent fewer days above 16 °C (60.8 °F) and are easier to achieve.

Over the full modeling period, the Basic Coordination Alternative and the Supply Driven Alternative, including both the LB Priority and LB Pro Rata approaches, perform similarly to the No Action Alternative and the CCS Comparative Baseline, meeting the preferred minimum performance level in 62 to 67 percent of futures. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform worse, meeting the preferred minimum performance level in 34 percent and 42 percent of futures, respectively. Performance is generally higher for all alternatives when compared by decade, but the same rankings among alternatives hold true through 2060. As the required number of days decreases (lower rows in the figure), robustness increases across all alternatives.

Overall, alternatives that limit the number of days exceeding 16 °C (60.8 °F), particularly the Enhanced Coordination and Maximum Operational Flexibility Alternatives, generally perform worse than the No Action Alternative and the CCS Comparative Baseline in maintaining temperatures beneficial for humpback chub spawning, but those same alternatives may limit smallmouth bass spawning.

Figure TA 8-20
Humpback Chub Spawning at Pearce Ferry: Robustness.
Percentage of futures in which the temperature at Pearce Ferry exceeds 16 °C in the days per year specified by each row in 90 percent or more of years.



The Representative Preferred Alternative meets the preferred minimum performance level in 53 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are the most robust, meeting the preferred minimum performance in 66-75 percent of futures. The Representative Preferred (58 percent), Maximum Operational Flexibility (56 percent), and Enhanced Coordination (51 percent) are slightly less robust.

As with the Little Colorado River and Havasu Creek, exceeding the 12 °C (53.6 °F) threshold creates thermal conditions that support mainstream humpback chub growth. While these warmer temperatures can benefit native humpback chub by enhancing growth and recruitment, temperatures exceeding 16 °C (60.8 °F) also favor smallmouth bass, which may increase predation and competition pressures on native fish populations. The comparative analysis of alternatives at the 12 °C (53.6 °F) and 16 °C (60.8 °F) thresholds is critical for identifying management scenarios that balance the needs of native and nonnative species. Alternatives that limit the number of days above these temperature thresholds (Enhanced Coordination and Maximum Operational Flexibility Alternatives) may help reduce smallmouth population growth but could also restrict opportunities for humpback chub reproduction.

Smallmouth Bass Population Growth

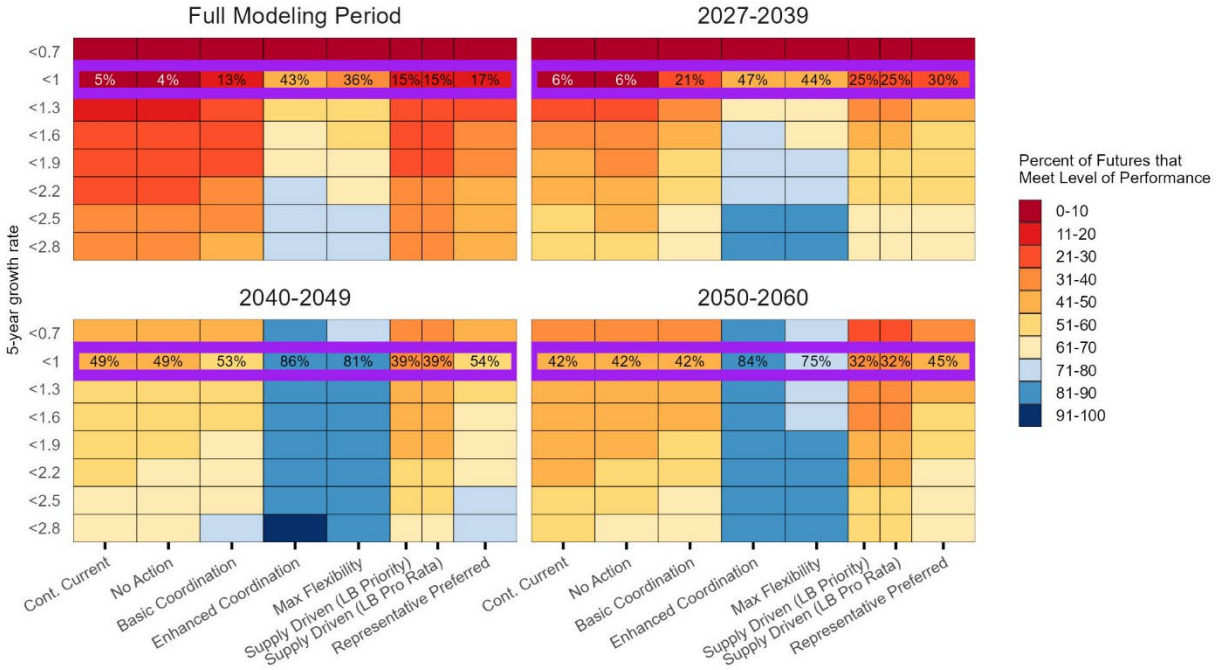
An analysis comparing the percentage of futures in which smallmouth bass lambdas are less than 1 was used to compare alternatives in controlling smallmouth bass survival and recruitment throughout the Grand Canyon. For each year and trace within an alternative, the predicted population growth rate, lambda, was calculated based on predicted water temperatures using the model described in Eppehimer et al. (2025). To keep the smallmouth bass population growth declining, lambda values would need to remain below 1.

The analysis below uses the 5-year product of lambda because it captures the cumulative effect of annual population growth rates and highlights conditions that could lead to sustained population expansion. Considering the 5-year lambda product means a single-year lambda could still exceed 1 but not necessarily result in positive or sustained population growth (Dibble et al. 2026; Pine et al. 2025; Eppehimer, D., GCMRC, personal communication). For consistency with previous analyses (i.e., Reclamation 2024), we use a threshold of less than 1 for analysis and comparison across alternatives.

Figure TA 8-21 reports the percentage of modeled futures in which the 5-year product of smallmouth bass population growth rate (lambda) at Lees Ferry always remains below the value specified in each row. The highlighted row identifies the preferred minimum performance level: 5-year lambda is always less than 1. Meeting the preferred minimum performance level means that, over any 5-year period, the population growth rate declined, decreasing the risk of smallmouth bass populations increasing and being established in the Grand Canyon. 5-year lambdas below 1 are favorable for native fish conservation, whereas values above 1 indicate the potential for increased predation and competition with native fishes. Higher rows represent lower 5-year lambda values that are more difficult to achieve, while lower rows represent higher values that are easier to achieve.

Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance level in 43 percent and 36 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative perform similarly and perform substantially worse than all other alternatives, meeting the preferred minimum performance level in 5 and 4 percent of futures, respectively. The Basic Coordination and Supply Driven Alternatives, including both the LB Priority and LB Pro Rata approaches, perform similarly to each other with relatively low performance related to the threshold. Across the range of thresholds shown in the figure, alternatives perform similarly at slightly higher 5-year lambda values, which are easier to achieve. For all alternatives, robustness is lowest in 2027–2039 because every modeled future begins with low initial reservoir conditions in 2027. In the second and third decades, the Enhanced Coordination and Maximum Operational Flexibility Alternatives achieve high scores (75 to 86 percent of futures), indicating they are robust at maintaining 5-year lambda below 1. The other alternatives meet the preferred minimum performance level between 32 and 54 percent of futures.

Figure TA 8-21
5-Year Smallmouth Bass Growth Rate: Robustness.
Percentage of futures in which the 5-year product of Smallmouth Bass growth rate (lambda) at Lees Ferry is always less than the value specified by each row

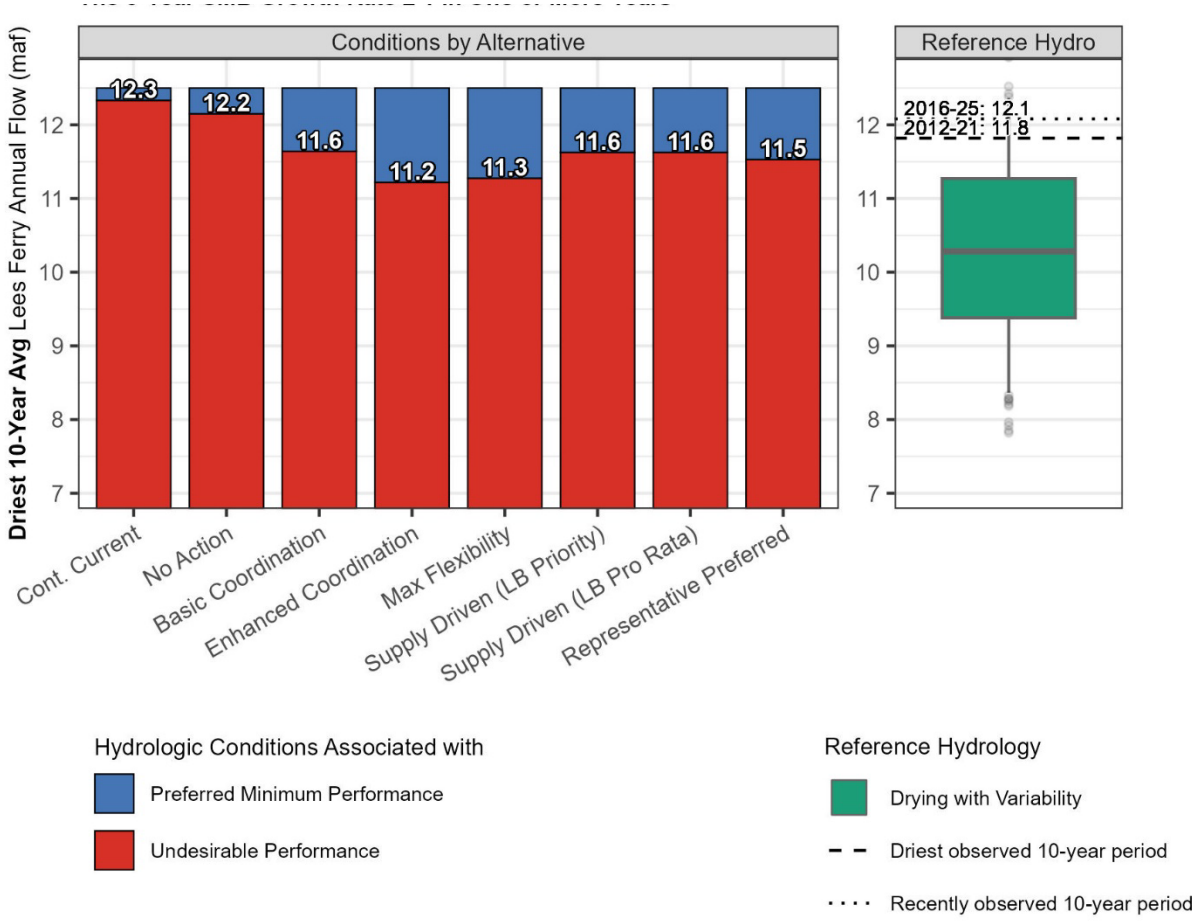


The Representative Preferred Alternative meets the preferred minimum performance level in 17 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination (47 percent) and Maximum Operational Flexibility (44 percent) Alternatives are the most robust, followed by the Representative Preferred Alternative (30 percent). The Supply Driven (both LB Priority and LB Pro Rata approaches) (25 percent) and Basic Coordination (21 percent) Alternatives are less robust, while the CCS Comparative Baseline and No Action Alternative are the least robust (both 6 percent).

Figure TA 8-22 below shows what flow conditions are likely to result in at least one occurrence of the 5-year lambda at or above 1.0, indicating conditions that could allow smallmouth bass populations to increase. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-21** above, which defined a future as successful when an alternative always kept the 5-year lambda below 1.0.

The driest 10-year average Lees Ferry natural flow was identified as a skillful predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows, along with the most recent and driest observed 10-year periods. The reference hydrology's median value is approximately 10.3 maf. The most recent 10-year average Lees Ferry annual flow (12.1 maf from 2016–2025) is represented by a dotted line for comparison, and the driest observed 10-year period averaged about 11.8 maf.

Figure TA 8-22
5-Year Smallmouth Bass Growth Rate: Vulnerability.
Conditions that could cause the 5-year smallmouth bass population growth rate to be at least 1 in one or more years



The CCS Comparative Baseline and No Action Alternative are the most vulnerable, being expected to result in undesirable performance under 10-year averages of 12.3 and 12.2 maf. The Basic Coordination and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives can withstand slightly drier conditions, expecting undesirable performance under 10-year averages of 11.6 maf. These alternatives are reasonably likely to result in undesirable performance because these conditions are similar to the driest historical 10-year period (11.8 maf), and about 90 percent or more of the traces in the Drying with Variability ensemble, which represents how hydrology could change in a drier future, are drier. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform slightly better, with undesirable performance likely under 10-year average flows of 11.2 and 11.3 maf. Although these flows have not occurred historically, they are still reasonably likely to be vulnerable because more than 75 percent of traces in the Drying with Variability ensemble are drier than these thresholds.

The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 11.5 maf or less. Compared to the historical periods shown in the reference

hydrology panel, this flow has not occurred before. Compared to the Drying with Variability ensemble that represents potential future hydrologic conditions, greater than 75 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

Water temperature inputs into the smallmouth bass model drive the lambda results. Based on the analysis of water temperature at Lees Ferry (see **Figure TA 8-9**), the Enhanced Coordination and Maximum Operational Flexibility Alternatives result in fewer days exceeding temperature thresholds (i.e., lower water temperatures), which generally decreases lambda relative to the other alternatives.

Smallmouth Bass Entrainment

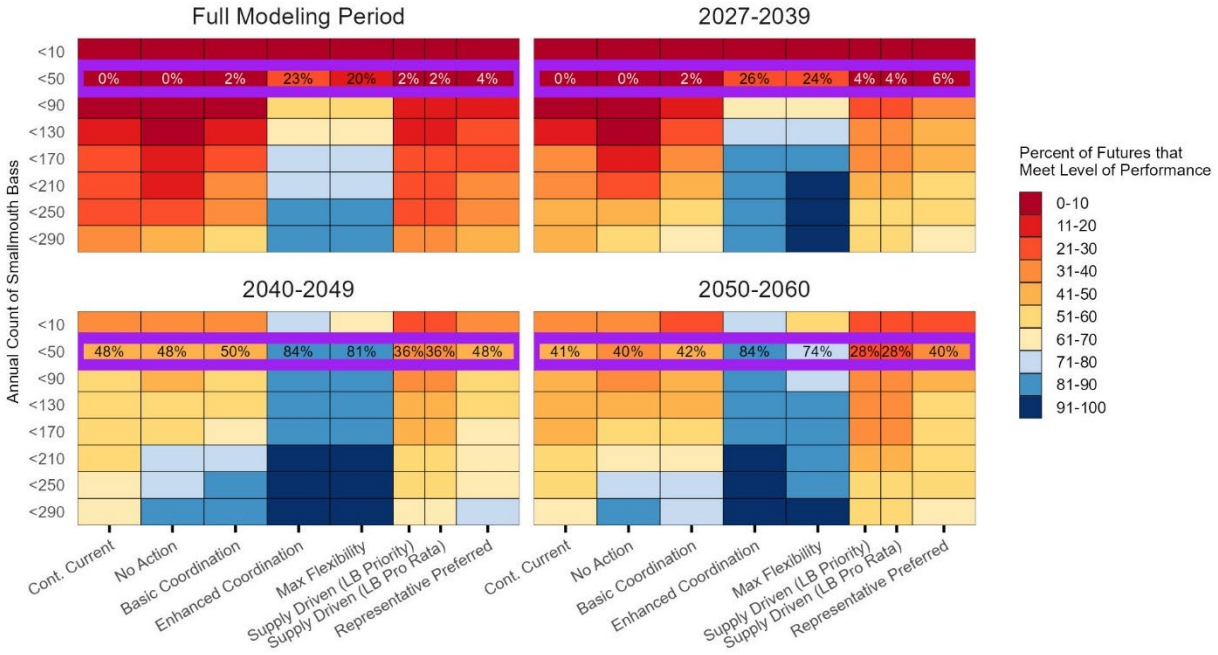
Entrainment of smallmouth bass through Glen Canyon Dam poses a threat to the native fish community, including humpback chub downstream. Data from the smallmouth bass model assess entrainment of adult smallmouth bass through Glen Canyon Dam. We use the annual elevation of Lake Powell to calculate the potential for entrainment and use a relative threshold of fewer than 50 adult individuals for assessment, as described in the methodology.

Figure TA 8-23 reports the percentage of modeled futures in which the annual number of adult smallmouth bass that are entrained through Glen Canyon Dam and survive remains below the number specified by each row. In addition to the 5-year product of smallmouth bass lambda, entrainment and survival are used to assess performance because they reflect the potential for repeated entrainment events to contribute to population establishment and growth in the Grand Canyon.

The highlighted row identifies the preferred minimum performance level: the annual number of adult smallmouth bass that are entrained and survive remains below 50 individuals in every year of each modeled future. This threshold was selected because 50 adults per year could represent more than a doubling of the population of reproductively capable fish, based on abundance estimates from 2022 and 2023 at the beginning of the invasion. This threshold was selected to compare alternative performance rather than assess a preferred entrainment threshold. Higher rows represent conditions allowing fewer adult fish to be entrained and are more difficult to achieve, while lower rows represent higher allowable counts and are easier to achieve.

Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance level in 23 percent and 20 percent of futures, respectively. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven Alternatives, including both the LB Priority and LB Pro Rata approaches, perform similarly and substantially worse, meeting the preferred minimum performance level in approximately 0 to 2 percent of futures. Across thresholds shown in the figure, alternatives perform similarly relative to each other at higher annual counts that are easier to achieve, and slightly lower counts that are more difficult to achieve. Results also indicate that lower Lake Powell elevations increase the probability of entrainment because warmer water, where smallmouth bass typically reside, aligns more closely with the dam penstocks at elevations approaching 3,490 feet (see **Figure TA 8-7** for an analysis of entrainment related to Lake Powell elevation). The percent of

Figure TA 8-23
Smallmouth Bass Entrainment and Survival: Robustness.
Percentage of futures in which the annual count of adult smallmouth bass that are entrained and survive is always less than amount specified by each row

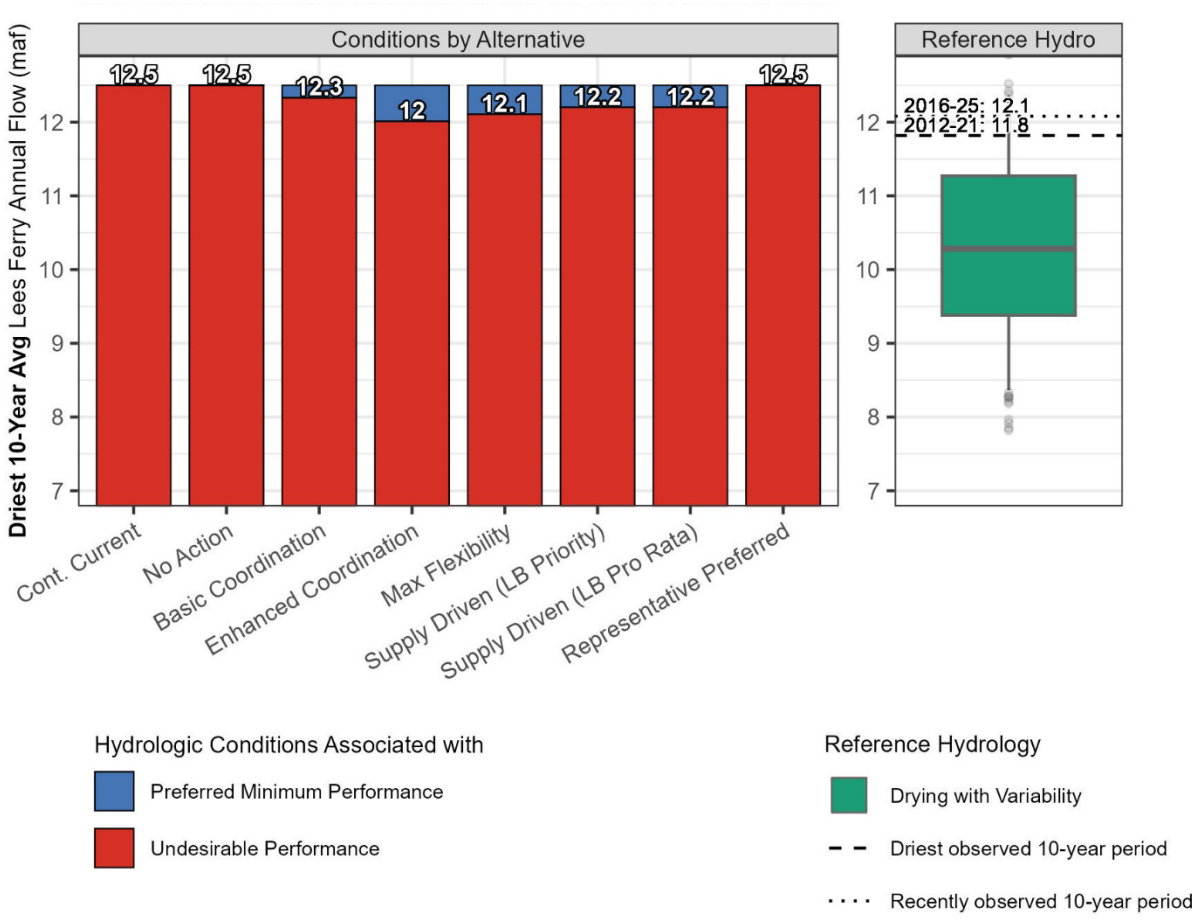


futures that meet the preferred minimum performance is lowest in the first decade because all modeled futures begin with Lake Powell elevation at 3,511 feet in 2027, which makes it difficult to maintain entrainment below 50 individuals. All alternatives perform better in the second and third decades, with Enhanced Coordination and Maximum Operational Flexibility performing the best, meeting the preferred minimum performance in 74 to 84 percent of futures.

The Representative Preferred Alternative meets the preferred minimum performance level in 4 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination (26 percent) and Maximum Operational Flexibility (24 percent) Alternatives are the most robust. The remaining alternatives perform poorly, meeting the preferred minimum performance in 0-6 percent of futures. Specifically, the Representative Preferred Alternative meets the preferred minimum performance in 6 percent of futures.

Figure TA 8-24 below shows which flow conditions are likely to result in one or more years with entrainment of 50 or more individuals. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-23** above, which defined a future as successful when an alternative maintained entrainment below 50 individuals. Higher entrainment levels increase the risk of downstream transfer of nonnative fish through Glen Canyon Dam above the current levels and conditions.

Figure TA 8-24
Smallmouth Bass Entrainment and Survival: Vulnerability.
Conditions that could cause the count of smallmouth bass entrained and surviving in any year to be 50 individuals or more



The driest 10-year average Lees Ferry natural flow was identified as a skillful predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented in the Drying with Variability ensemble, which represents how future hydrology could change in a drier future. In addition, the most recent and driest observed 10-year periods are shown with dotted and dashed lines. The reference hydrology's median value is approximately 10.3 maf. The most recent 10-year average Lees Ferry annual flow is 12.1 maf (from 2016–2025), and the driest observed 10-year period averaged about 11.8 maf (2012–2021).

All alternatives and the CCS Comparative Baseline are likely to be vulnerable beginning at 10-year averages between 12 and 12.5 maf. All alternatives are reasonably likely to experience at least one year with 50 or more smallmouth bass entrained because similar conditions have occurred historically, and over 90 percent of traces in the Drying with Variability ensemble exhibit drier conditions. Although all alternatives are likely vulnerable over the full 34-year modeling period, recall that the Enhanced Coordination and Maximum Operational Flexibility Alternatives exhibit strong

robustness later in the modeling period, after having time to recover from low initial reservoir conditions in 2027 (see **Figure TA 8-23**, above).

The Representative Preferred Alternative is likely to be vulnerable if the driest 10-year average Lees Ferry annual flow is 12.5 maf or less. Compared to the historical periods shown in the reference hydrology panel, this flow has occurred before. Compared to the Drying with Variability ensemble that represents potential future hydrologic conditions, approximately 90 percent of the traces have a 10-year period drier than the vulnerability threshold for the Representative Preferred Alternative.

TA 8.2.4 Issue 3: Lower reservoir elevations have reduced lake habitat and extended river inflows, including about 30 miles on the Colorado River and 20 miles on the Virgin River, with similar extensions observed at Las Vegas Bay, Echo Bay, and other locations in Lake Mead. How will these inflow changes affect the quantity and quality of Lake Mead, wetland, and riverine inflow habitats?

The Lower Basin from Lake Mead to the SIB has experienced ecological changes driven by fluctuations in reservoir elevations and tributary inflows. These changes affect the quantity and quality of aquatic habitats in both lake and inflow areas, with consequences for native, nonnative, and recreationally important fish species. Lower lake elevations reduce shoreline habitat for sportfish and razorback sucker, while simultaneously extending riverine inflow habitats on the Colorado River, Virgin River, and other tributaries. Such shifts may alter designated critical habitat for razorback sucker and influence the distribution of native species, including humpback chub and razorback sucker. Spawning and nursery habitats for razorback sucker may change with increases in elevation of Lake Mead and could become limited. Pearce Ferry Rapid functions as a natural barrier to fish movement (native and nonnative), but at elevations above 1,090 feet, the rapid no longer serves as a barrier. However, elevations below 1,000 feet compromise hydropower generation.

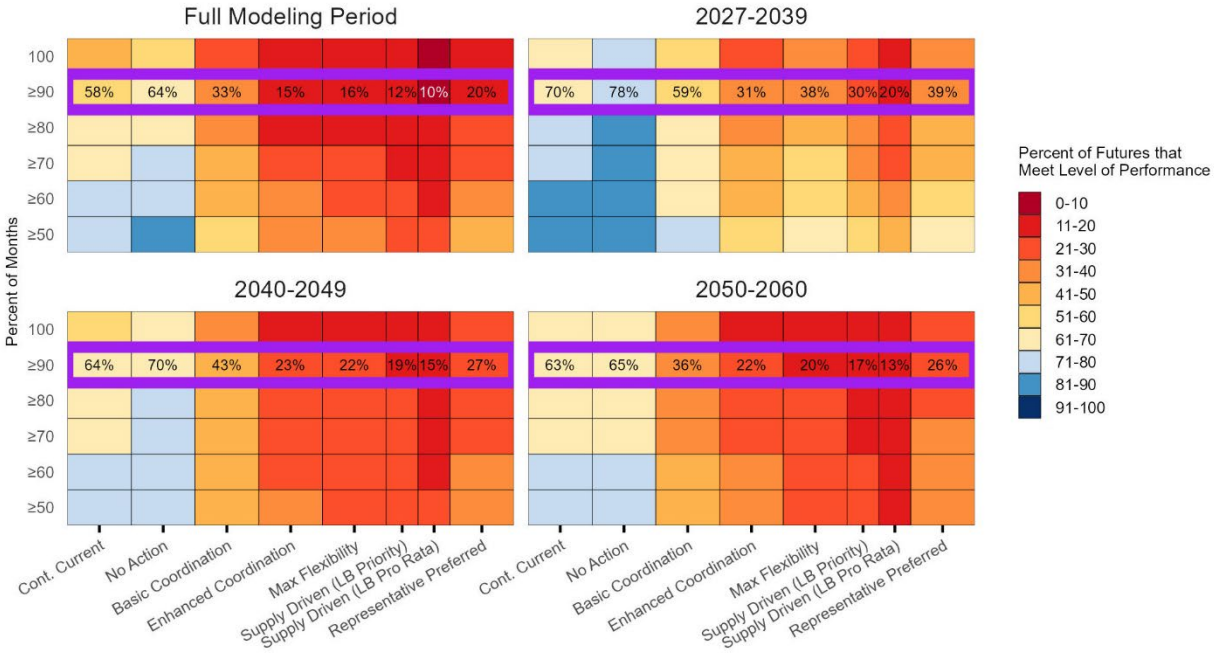
To evaluate these changes, indicators include monitoring data on sportfish catch, shifts in the distribution and abundance of native fish species, and the extent and quality of inflow and shoreline spawning habitats. Bathymetric analyses or lake elevation data provide critical insight into thresholds where razorback sucker spawning habitats become desiccated or reduced. Thresholds also include lake elevations outside the historical 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead period (2008–2025) (FWS 2007), which represent untested conditions for fish communities within Lake Mead. Assessment methods integrate monitoring data from AZGFD, NDOW, and the LCR MSCP, as well as DMDU analyses of lake elevation scenarios to evaluate differences in aquatic habitat and fish community response under alternative management strategies.

Thresholds used in the analysis include: (1) Lake Mead elevation above 1,090 feet, at which Pearce Ferry Rapid becomes inundated and no longer functions as a barrier to upstream fish passage, and (2) lake elevations at which razorback sucker spawning locations in the lake are desiccated or, more broadly, when elevations and habitats fall outside the historical range of lake elevations observed during 2015–2025. These thresholds are biologically significant because they may influence the distribution, survival, and reproduction of both native fish populations and sportfish in Lake Mead and represent conditions not previously experienced in recent decades. In all cases, an important

assumption is that fisheries management practices, such as stocking of listed fish species, would generally continue as they have during 2008–present.

We analyzed how each alternative affects the likelihood of sustaining Pearce Ferry Rapid as a natural deterrent to upstream movement. Based on current conditions and historic fish captures relative to lake elevation, it is thought that if Lake Mead remains below approximately 1,090 feet and follows the historical levels observed during the interim guideline period, the current species composition and population dynamics within the Grand Canyon and Lake Mead would remain similar. The analysis sheds light on upstream movement by native species, such as razorback sucker, while also allowing for upstream movement of nonnative fishes into the Grand Canyon. The last time Lake Mead elevation was above 1,090 feet was in May 2020 (Reclamation 2026). In **Figure TA 8-25**, the percentage of modeled futures for each alternative in which Lake Mead elevation remains below 1,090 feet is evaluated according to the percentage of months specified by each row. The highlighted row identifies the preferred minimum performance level, specifically, that Lake Mead elevation remains below 1,090 feet in at least 90 percent of months within each modeled future. This threshold reflects recent historical conditions, as Lake Mead elevation has been below 1,090 feet in approximately 94.3 percent of months from January 2016 to March 2026. This period was selected because it more accurately reflects recent conditions at Pearce Ferry Rapid.

Figure TA 8-25
Pearce Ferry Rapids as Nonnative Fish Barrier: Robustness.
Percentage of futures in which Lake Mead elevation stays below 1,090 feet in the percentage of months specified by each row



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at maintaining Pearce Ferry Rapid as a barrier that helps contain nonnative fish species and limit the Grand Canyon's exposure to additional nonnative fish pressure. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which Lake Mead remains below 1,090 feet for a greater share of months and are more difficult to achieve, while lower rows represent less restrictive conditions that are easier to achieve.

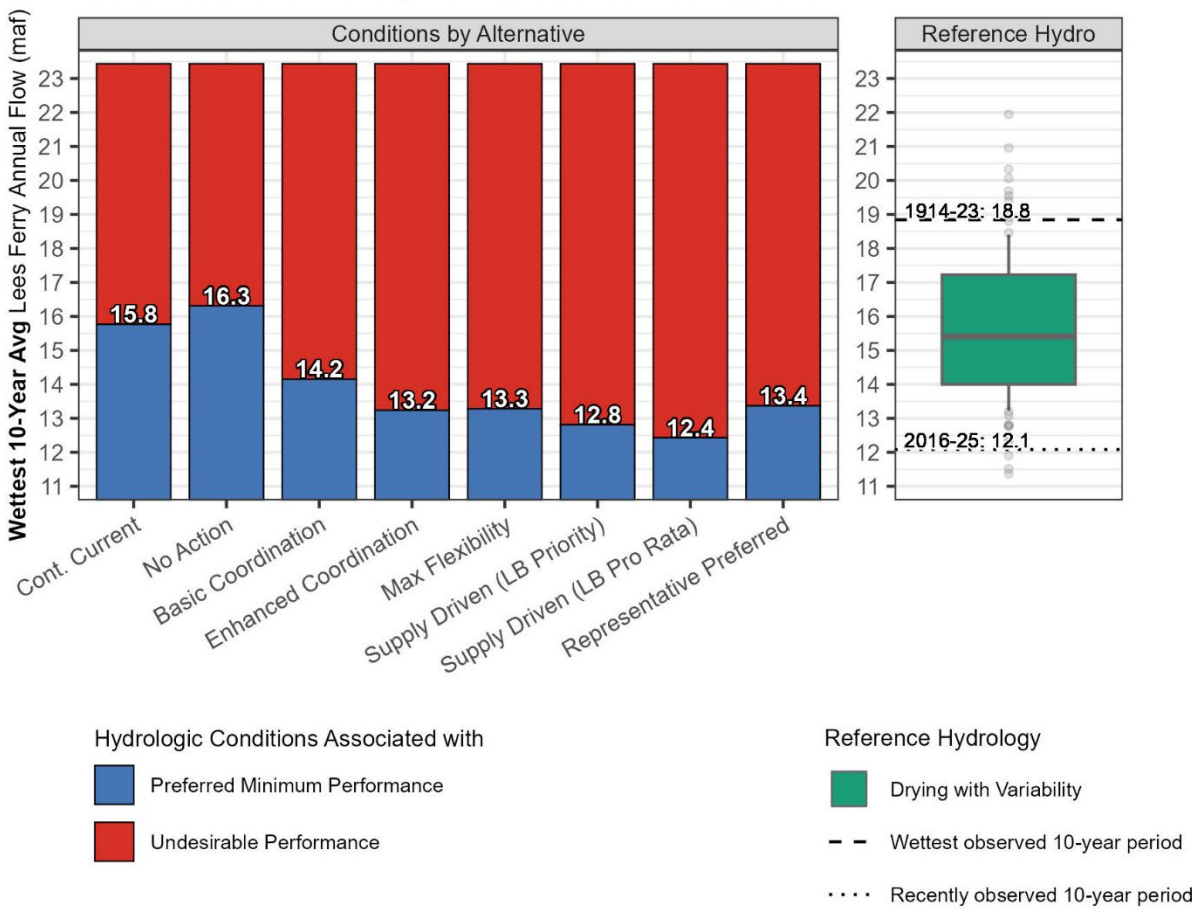
Over the full modeling period, the No Action Alternative is the most robust, meeting the preferred minimum performance level in 64 percent of futures. The CCS Comparative Baseline performs similarly, meeting the threshold in 58 percent of futures. All other alternatives perform substantially worse, with differences exceeding 10 percent relative to the No Action Alternative and the CCS Comparative Baseline. Among the action alternatives, the Basic Coordination Alternative performs the best, meeting the preferred minimum performance level in 33 percent of futures. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven Alternatives, including both the LB Priority and LB Pro Rata approaches, are the least robust, meeting the preferred minimum performance level between 10 to 16 percent of futures.

Over the different decadal modeling periods, the No Action Alternative is the most robust, meeting the preferred minimum performance level between 65 and 78 percent of futures. The CCS Comparative Baseline performs similarly, meeting the threshold in 63 to 70 percent of futures. All other alternatives perform substantially worse, with differences exceeding 10 percent relative to the No Action Alternative and the CCS Comparative Baseline. Among the action alternatives, the Basic Coordination Alternative performs the best, meeting the preferred minimum performance level in 36 to 59 percent of futures.

The Representative Preferred Alternative meets the minimum performance level (at least 90 percent of months) in 20 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The No Action Alternative (78 percent), CCS Comparative Baseline (70 percent), and Basic Coordination Alternative (59 percent) are the most robust. The Representative Preferred (39 percent), Maximum Operational Flexibility (38 percent), Enhanced Coordination (31 percent), and Supply Driven (LB Priority Approach) (30 percent) Alternatives are less robust. The Supply Driven (LB Pro Rata approach) Alternative is the least robust (20 percent).

Figure TA 8-26 below shows what flow conditions are likely to result with Lake Mead elevations above 1,090 feet in more than 10 percent of months. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-25** above, which defined a future as successful when an alternative maintained Lake Mead elevations below 1,090 feet at least 90 percent of the time.

Figure TA 8-26
Pearce Ferry Rapid remains a barrier to upstream fish passage: Vulnerability. Conditions that could cause Lake Mead elevation to go above 1,090 feet in more than 10 percent of months



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

The wettest 10-year average Lees Ferry natural flow was identified as a skillful and highly relevant predictor of vulnerability. The reference hydrology panel shows the range of wettest 10-year average flows represented in the Drying with Variability ensemble, along with the most recent and wettest observed 10-year periods. The reference hydrology's median value is approximately 15.4 maf, and the most recent 10-year average Lees Ferry annual flow (12.1 maf for 2016–2025) is shown as a dotted line for comparison. The wettest 10-year period in the observed record averaged about 18.8 maf (1914–1923) and is represented by a dashed line.

The Supply Driven (both LB Priority and LB Pro Rata approaches), Enhanced Coordination, and Maximum Operational Flexibility Alternatives are the most vulnerable, being vulnerable to elevations above 1,090 feet more than 10 percent of the time in 10-year average flows of 12.4 to 13.2

maf or wetter. About 90 percent or more of traces in the Drying with Variability ensemble exhibit these conditions.

The Basic Coordination and Representative Preferred Alternatives are slightly less vulnerable, being vulnerable under 10-year averages of 14.2 and 13.4 maf or wetter. About 75 percent of traces in the Drying with Variability ensemble exhibit these conditions.

The No Action Alternative and CCS Comparative Baseline are the least vulnerable, being vulnerable under 10-year averages of 16.3 and 15.8 maf or wetter. Less than 50 percent of traces in the Drying with Variability ensemble exhibit these conditions.

The wettest 10-year period in the observed record averaged about 18.8 maf, indicating that all alternatives are susceptible to conditions similar to those experienced in the early 1900s. However, all alternatives would be expected to satisfy the preferred minimum performance level if the wettest 10-year period is no wetter than the most recent observed 10-year average of 12.1 maf.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Mead elevations exceeding 1,090 feet in at least 10 percent of months in a 10-year average flow of 13.4 maf or wetter. This alternative may or may not be vulnerable in the next 10 years because different aspects of the reference hydrology panel conflict. Considering the Drying with Variability ensemble, about 75 percent of traces are greater than 13.4 maf, suggesting this alternative is reasonably likely to be vulnerable. However, the recently observed 10-year period is below 13.4 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

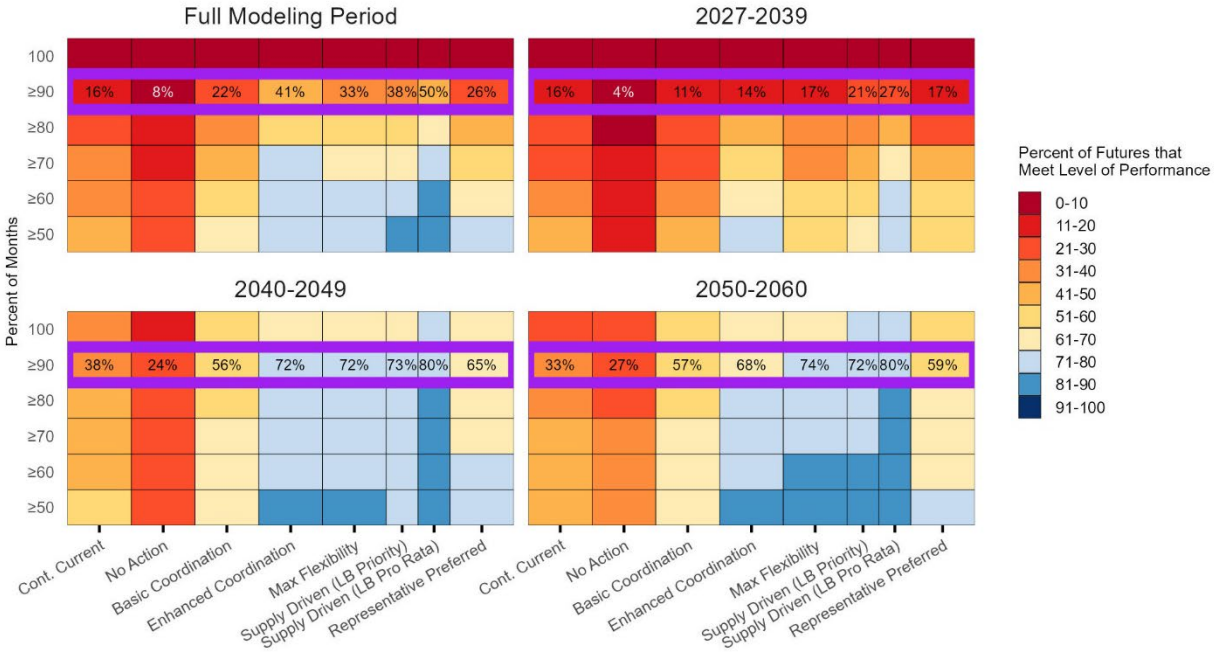
Alternatives that allow for more flow and Lake Mead storage perform worse than the No Action Alternative and CCS Comparative Baseline for native fishes such as razorback sucker, flannelmouth sucker, or even humpback chub that may wish to move from downstream to upstream and into the Grand Canyon. Thus, under a less robust scenario, native fish movement upstream out of Lake Mead would occur more frequently, which could allow for additional spawning and genetic mixing within the Colorado River in the Grand Canyon but would also allow for more competition from nonnative fish moving into the western Grand Canyon, where native fish abundance currently dominates the fish community.

To explore shoreline habitat availability in Lake Mead, we used the 2008–2026 lake elevation data as a proxy to determine whether there would be suitable littoral shoreline habitats for the fish community in Lake Mead. An important assumption is that, at any given lake elevation, the amount of littoral shoreline habitat available to fishes and other aquatic species is related to the elevations and shoreline habitats present from 2008 to March 2026. The lowest elevation observed in Lake Mead from 2008 to March 2026 was 1,040.92 feet in July 2022. Because it appears that the current fish and aquatic species assemblage within Lake Mead survived at that lake elevation, we presume the shoreline habitat at that elevation is suitable for the overall current fish community.

In **Figure TA 8-27**, the percentage of modeled futures for each alternative in which Lake Mead elevation remains above the historical minimum elevation of 1,040.92 feet is evaluated according to the percentage of months specified by each row. The highlighted row identifies the preferred minimum performance level, specifically, that Lake Mead elevation remains at or above 1,040.92 feet in at least 90 percent of months within each modeled future. Using the 90 percent threshold allows the analysis to reflect scenarios in which Lake Mead remains at or above the historical minimum elevation for most months during the full modeling period from 2027 to 2060.

Alternatives that achieve this preferred minimum performance level in a higher percentage of futures are more effective at maintaining Lake Mead above its historical minimum elevation. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which Lake Mead remains above the threshold in a greater share of months and are more difficult to achieve, while lower rows represent less restrictive conditions that are easier to achieve.

Figure TA 8-27
Lake Mead Historical Minimum Shoreline Habitat: Robustness.
Percentage of futures in which Lake Mead elevation remains above the historical minimum elevation (1,040.92 feet) in the percentage of months specified by each row



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Over the full modeling period, the No Action Alternative is the least robust, meeting the preferred minimum performance level in 8 percent of futures. The CCS Comparative Baseline improves performance to 16 percent of futures, while the Basic Coordination Alternative increases

performance to 22 percent of futures. The Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative, Supply Driven (LB Priority) Alternative, and Supply Driven (LB Pro Rata) Alternative perform better, meeting the preferred minimum performance level in 41 percent, 33 percent, 38 percent, and 50 percent of futures, respectively. The Supply Driven Alternative under the LB Pro Rata approach performs the best, meeting the preferred minimum performance level in 50 percent of futures and showing the highest likelihood of maintaining Lake Mead at or above 1,040.92 feet. Alternative performance rankings remain similar in future decades, but tend to improve in robustness from 2040–2060. Futures and alternatives with more water, representing higher lake elevations, would likely yield more robust performance.

The Representative Preferred Alternative meets the minimum performance level (at least 90 percent of months) in 26 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Supply Driven Alternative is most robust, meeting the preferred minimum performance in 27 percent of futures under the LB Pro Rata approach and 21 percent of futures under the LB Priority Approach. No Action (4 percent) is the least robust alternative. The Representative Preferred Alternative (17 percent) performs in the middle, similar to the CCS Comparative Baseline (16 percent), and the Basic Coordination (11 percent), Enhanced Coordination (14 percent) and Maximum Operational Flexibility (17 percent) Alternatives.

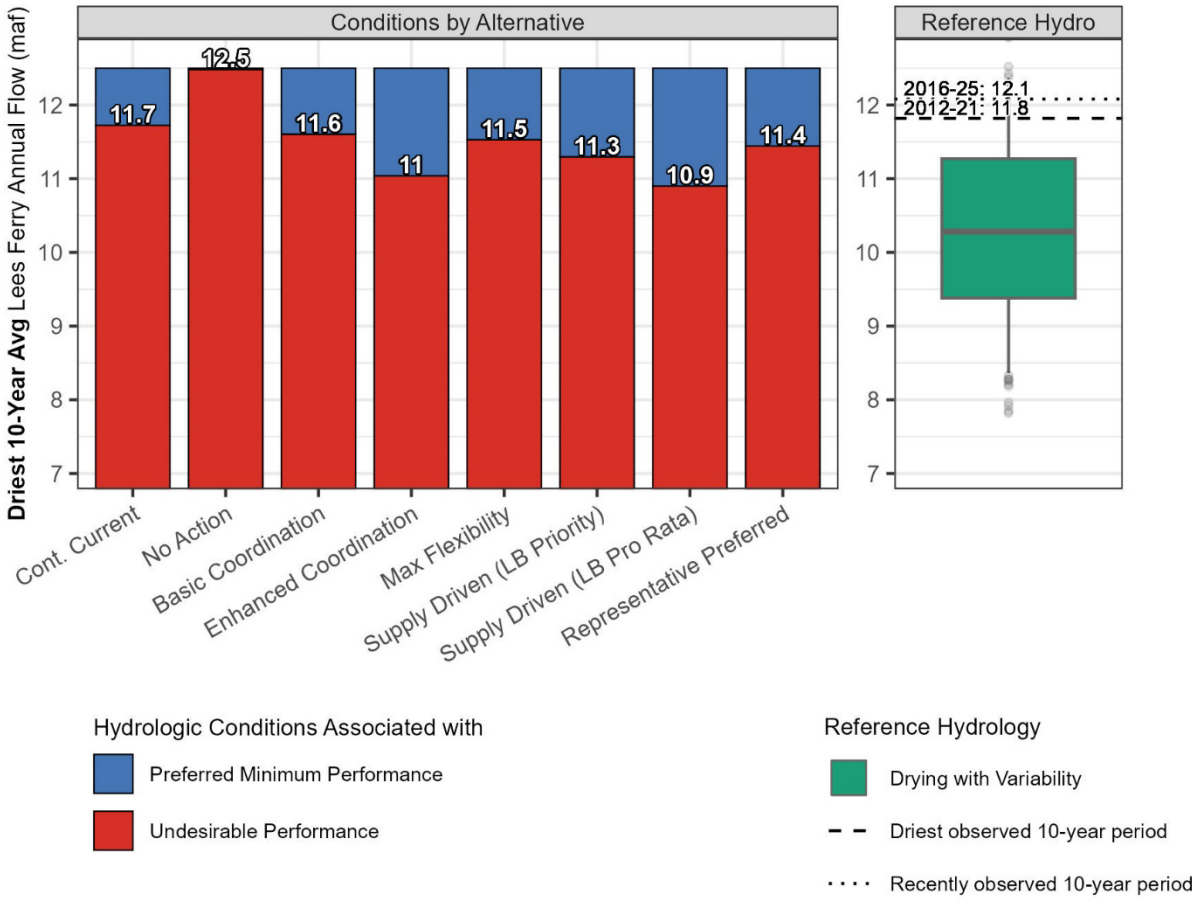
Figure TA 8-28 below shows what flow conditions are likely to result in Lake Mead elevation falling below 1,040.92 feet more than 10 percent of the time. This definition of undesirable performance is based on the highlighted row in **Figure TA 8-27** above, which defined a future as successful when an alternative maintained elevations above 1,040.92 feet at least 90 percent of the time.

The driest 10-year average Lees Ferry natural flow was identified as a skillful predictor of undesirable performance. The reference hydrology panel shows the range of driest 10-year average flows represented in the reference hydrology, along with the driest observed 10-year period in the historical record. The reference hydrology's median value is approximately 10.3 maf, and the driest 10-year average Lees Ferry annual flow observed in the historical record (11.8 maf from 2012–2021) is represented by a dashed line for comparison.

All action alternatives are vulnerable to Lake Mead elevation falling below the historical minimum (1,040.92 feet) more than 10 percent of months under flows between 10.9 maf (Supply Driven LB [Pro Rata], the least vulnerable) and 11.7 maf (CCS Comparative Baseline, more vulnerable) or drier. Similar but slightly wetter conditions have occurred historically (11.8 maf), and greater than 75 percent or more traces in the Drying with Variability ensemble exhibit drier conditions. The No Action Alternative is vulnerable under flows of 12.5 maf or drier, which has occurred historically and occurs in nearly all traces in the Drying with Variability ensemble.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to 10 percent or more months falling below 1,040.92 feet under 10-year averages of 11.4 maf or drier. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in more than 75 percent of the traces in the Drying with Variability ensemble, which represents a drier future.

Figure TA 8-28
Lake Mead Historical Minimum Shoreline Habitat: Vulnerability. Conditions that could cause Lake Mead to fall below 1040.92 feet in more than 10 percent of months



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

The fish community in Lake Mead has adapted to fluctuating lake elevations for decades (Rogers et al. 2025a). If lake elevations remain within the historical range observed from 2008 to March 2026, the conditions that support current species composition and population dynamics are likely to persist. If the Lake Mead elevation remains relatively stable and within the historical elevations, the aquatic community would likely continue to find spawning and/or nursery habitats. However, prolonged low-elevation periods may increase the vulnerability of shoreline habitats used by aquatic species by reducing spawning and/or nursery habitat beyond what those species have routinely experienced in this system from 2008 to March 2026.

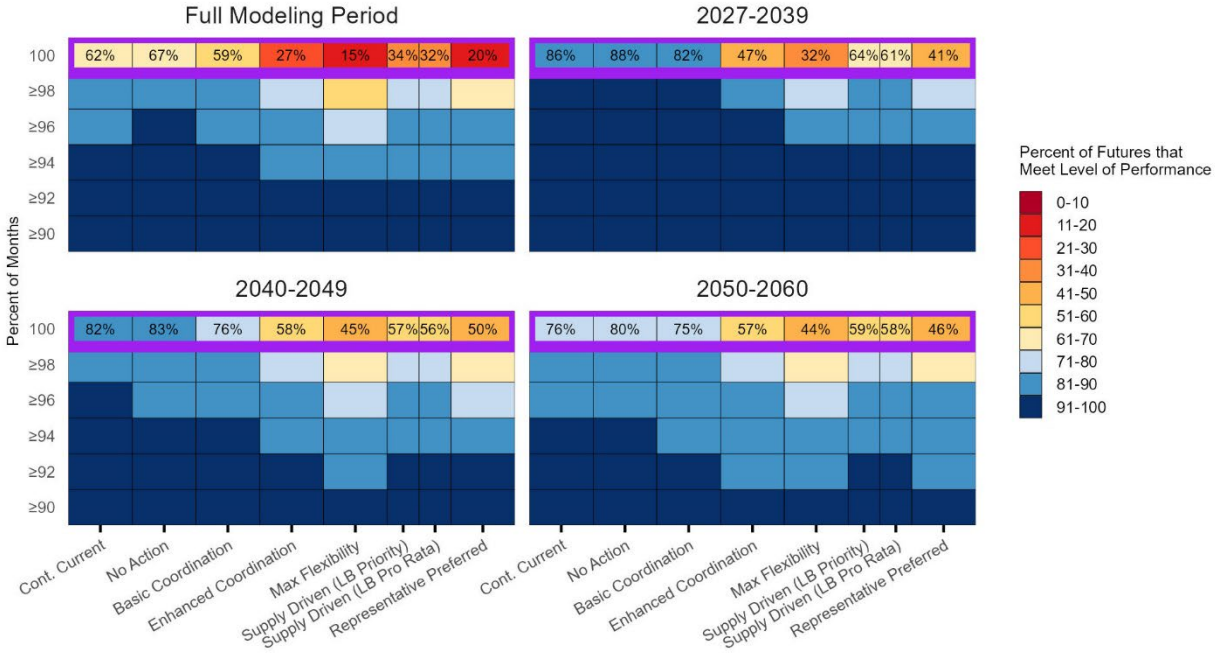
TA 8.2.5 Issue 4: How will modifications in water quantity, timing, temperature, and quality released from Hoover Dam affect the Lower Colorado River, including LCR MSCP Reaches 2 through 6 (Hoover Dam to Davis Dam and Lake Mohave; Davis Dam to Parker Dam and Lake Havasu; Parker Dam to Cibola Gage; Cibola Gage to Imperial Dam and Imperial Reservoir; and Imperial Dam to the Northerly International Boundary)?

Although mitigation measures are already in place through prior ESA consultation, the EIS analyzes river flows of Hoover Dam to assess how different operational alternatives may affect aquatic resources within the NEPA framework. If the alternatives stay within historical flow-release levels from Hoover Dam, the current fish species composition and population dynamics will likely remain unchanged. However, modified flows from Hoover Dam to Imperial Dam, along with associated effects of timing, temperature, and water quality, may influence the habitats and abundances of razorback sucker and bonytail, as well as the backwater and riverine habitats that support these endangered and other native fishes. Flow modifications may also impact known razorback sucker spawning sites, while flannelmouth sucker downstream of Davis Dam to Parker Dam could similarly be affected. In addition, desert pupfish inhabiting off-channel ponds in the Lower Colorado River may experience impacts from modified flows that could fall outside of historical 2008–2025 bounds, particularly if flooding of constructed refuge ponds occurred. Furthermore, the presence of flathead catfish downstream of the Cibola gage to Imperial Dam poses an additional concern, as reduced flows may allow this predator to access upper reaches, increasing risks to endangered and other native fish populations. Impact indicators include fish habitats, distributions, and the assumption that populations are influenced by dam releases and flow conditions, which also affect the extent and availability of backwater areas. In addition, the location, size, and overall suitability of razorback sucker spawning sites could vary across different flow regimes, highlighting the importance of flow management in maintaining critical life-history habitats. Assessment methods include reports and monitoring data from agencies such as AZGFD, NDOW, the California Department of Fish and Wildlife, Reclamation, LCR MSCP, and the FWS. In all cases, an important assumption is that fisheries management practices, such as stocking of listed and other fish species, would generally continue as they have from 2008 to the present.

In **Figure TA 8-29**, the percentage of modeled futures for each alternative in which monthly releases from Hoover Dam remain within the range observed during the 2007 Interim Guidelines period (2008 to 2025) is evaluated according to the percentage of months specified by each row. The highlighted row identifies the preferred minimum performance level, specifically, that monthly releases remain within the historical range in 100 percent of months within each modeled future.

Alternatives that achieve this preferred performance level in a higher percentage of futures are more effective at maintaining releases within the historically observed range. Conversely, alternatives meeting this threshold in a lower percentage of futures are less effective in this regard. Higher rows represent conditions in which releases remain within the historical range for a greater share of months and are more difficult to achieve, while lower rows represent less restrictive conditions that are easier to achieve.

Figure TA 8-29
Below Hoover Monthly Flows: Robustness.
Percentage of futures in which monthly releases from Hoover Dam are within the range observed during the 2007 Interim Guidelines period in the percentage of months specified by each row



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Over the full modeling period, the No Action Alternative, CCS Comparative Baseline, and Basic Coordination Alternative perform similarly and are the most robust, meeting the preferred performance level in 67 percent, 62 percent, and 59 percent of futures, respectively. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs somewhat lower, meeting the preferred performance level in 34 percent of futures under the LB Priority approach and 32 percent under the LB Pro Rata approach. The Enhanced Coordination Alternative performs similarly to the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at 27 percent of futures, while the Maximum Operational Flexibility Alternative performs the worst, meeting the preferred performance level in only 15 percent of futures. Despite these differences, results indicate that all alternatives maintain releases within the historical range for more than 92 percent of months across all modeled futures.

Decadal modeling shows the No Action Alternative, CCS Comparative Baseline, and Basic Coordination Alternative perform similarly and are the most robust, meeting the preferred performance level in 75 to 88 percent of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs somewhat lower, meeting the preferred performance level in 56 to 64 percent of futures. The Enhanced Coordination Alternative performs similarly to the

Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at 47 to 58 percent of futures, while the Maximum Operational Flexibility Alternative performs the worst, meeting the preferred performance level in 32 to 45 percent of futures. Despite these differences, the results indicate that all alternatives maintain releases within the historical range in more than 90 percent of months across all modeled decadal futures.

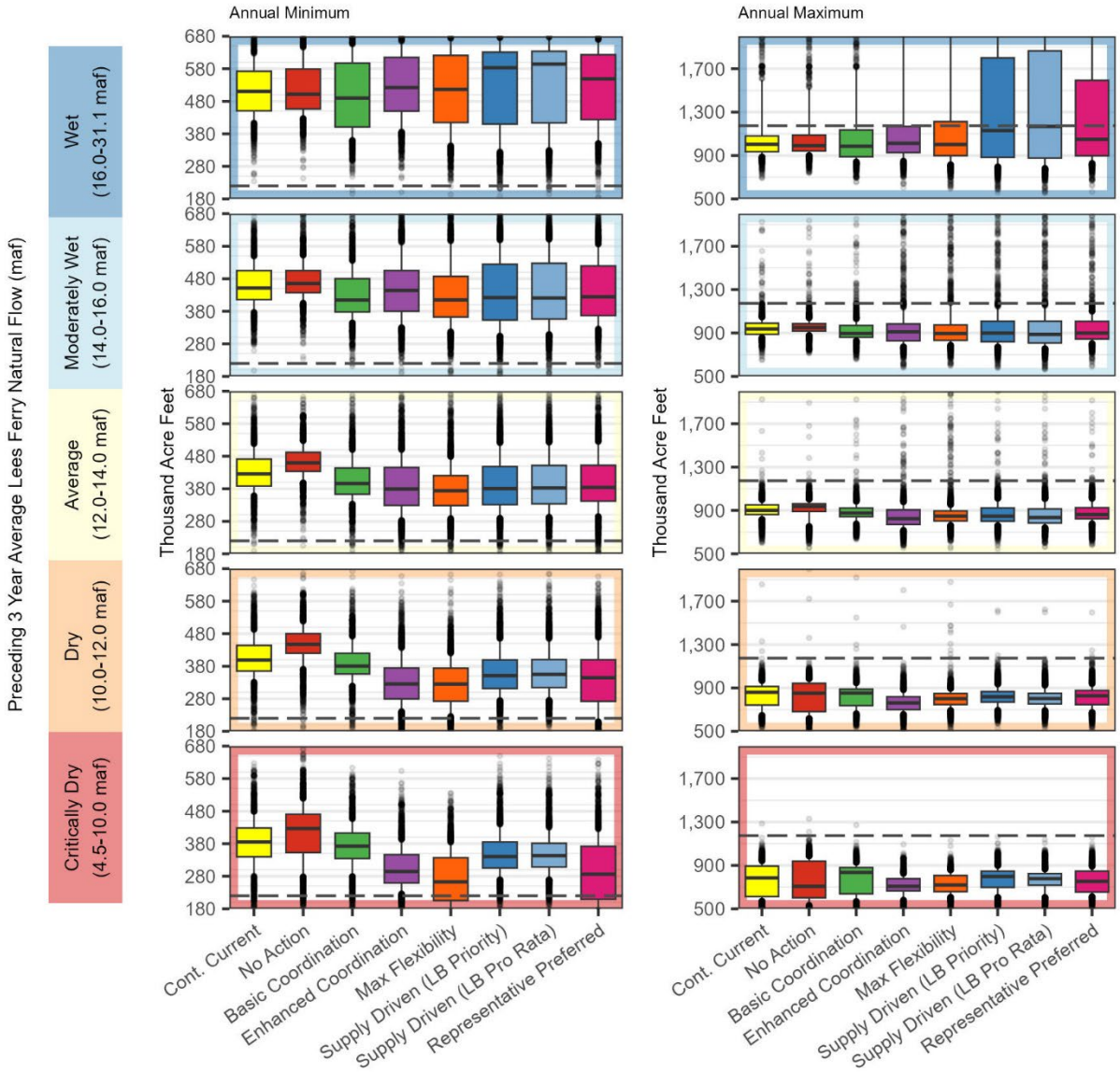
The Representative Preferred Alternative meets the minimum performance level (100 percent of months) in 20 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The No Action Alternative (88 percent), CCS Comparative Baseline (86 percent), and Basic Coordination Alternative (82 percent) are most robust. The Maximum Operational Flexibility (32 percent), Representative Preferred (41 percent), and Enhanced Coordination (47 percent) Alternatives are least robust in the 2027-2039 modeling period. The Supply Driven Alternative (both LB Priority and Pro Rata approaches) performs in the middle, achieving monthly releases from Hoover Dam that fall within the range observed during the Interim Guidelines in 100 percent of months in 64 percent and 61 percent of futures respectively.

Figure TA 8-30 shows monthly release volumes from Hoover Dam under each alternative. The left column reports the smallest monthly release in each year, and the right column reports the maximum monthly release in each year, both in thousand acre-feet (kaf). Each row represents a range of the preceding 3-year average inflows at Lees Ferry, from Wet conditions at the top (16.0–31.1 maf) to Critically Dry at the bottom (4.5–10.0 maf). The colored boxplots depict the distribution of releases under each alternative, with longer boxes indicating greater variability. Dashed lines represent the historical minimum (left column) and maximum (right column) monthly releases observed between 2008 and 2025. For the minimum release panels, outcomes are considered favorable when boxplots occur above the reference line at 220 kaf, while for the maximum release panels, outcomes are considered favorable when boxplots occur below the reference line at 1,174 kaf.

In the Wet Flow Category, most alternatives exhibit similar distributions of minimum and maximum monthly releases, indicating comparable operational responses during high-inflow periods. The exception is the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which tends to result in annual maximum monthly releases much higher than the other alternatives. As hydrologic conditions become drier, differences in annual minimum releases become more apparent. The No Action and Basic Coordination Alternative and CCS Comparative Baseline maintain relatively higher release volumes in the Critically Dry Flow Category, indicating continued high releases even during drought scenarios.

In contrast, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives result in lower minimum releases in drier flow categories. In the Critically Dry Flow Category, minimum releases remain above the 220 kaf reference line in about 90 percent or more years, except for the Maximum Operational Flexibility Alternative, which stays above in less than 75 percent of years. The results of the Representative Preferred Alternative box plots are within the range analyzed across the other alternatives.

Figure TA 8-30
Hoover Dam Monthly Releases Under Varying 3-Year Average Lees Ferry Inflows with Alternative Futures. Boxplots Show the Distribution of Annual Minimum (Left) and Annual Maximum (Right) Monthly Releases Across Simulated Futures, Thousand Acre-Feet



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

These patterns suggest that the No Action and Basic Coordination Alternatives and CCS Comparative Baseline sustain higher release volumes during drought conditions, which may increase the rate of decline in Lake Mead's elevation. The other alternatives implement larger shortage volumes, which may help maintain Lake Mead elevations closer to recent historical levels (at or above 1,040.92 feet, the lowest elevation Lake Mead has reached) while continuing to support aquatic habitats in the LCR MSCP reaches downstream of Hoover Dam. In combination with the patterns shown in **Figure TA 8-29**, these results suggest that the LCR MSCP reaches will likely remain relatively similar to conditions observed during the 2008–2025 time period.

The Representative Preferred Alternative exhibits the following outcomes for the Dry Flow Category: For the annual maximum flow, the median was 826.9 kaf, with 25th and 75th percentiles of 746.4 and 876.6 kaf. The annual minimum flow median was 344.6 kaf with 25th and 75th percentiles of 272.3 and 399.9 kaf. The Representative Preferred Alternative exhibits the following outcomes with respect to the Critically Dry Flow Category: For the annual maximum flow, the median was 752.8 kaf with 25th and 75th percentiles of 654.1 and 847.2 kaf. Finally, for the annual minimum flow, the median was 286.4 kaf, with 25th and 75th percentiles of 209.1 and 372.0 kaf. With respect to the critical thresholds of 220 and 1,174 kaf, the Representative Preferred Alternative falls within this threshold in about 75 percent of years in the Dry and Critically Dry Categories.

Within the LCR MSCP, the highest priority of the habitat conservation plan is the protection and preservation of backwater, isolated ponds, refuge (predator-free), and marsh habitats, especially with respect to areas occupied by ESA-listed species (LCR MSCP 2024). These areas are vital for maintaining the ecological integrity and biodiversity of the Lower Basin (Holmquist-Johnson et al. 2016; LCR MSCP 2024) and for allowing ESA-listed species to complete their life cycles. Because downstream habitats are largely re-regulated by Hoover Dam releases, changes in aquatic habitat are reflected in the patterns of those releases. Further, elevations and flows at Lake Mohave and Lake Havasu follow a guide curve and stay nearly constant across alternatives following releases from Hoover Dam. Multiple scenarios involving downstream impoundments were modeled and evaluated, but no significant differences were found to warrant further analysis at those locations. As a result, this analysis focuses on releases from Hoover Dam as a surrogate for all impoundments and features downstream. As described, modeled results suggest that most alternatives downstream of Hoover Dam would result in similar future conditions for fish in terms of modeled flows. These flows would also presumably influence water temperature and water quality in ways comparable to conditions experienced from 2008 to 2025, assuming similar fisheries and aquatic management practices continue. As a result, habitats within the LCR MSCP reaches are expected to remain generally similar to historical conditions, and fish communities would likely remain comparable to those observed during the 2008 to 2025 period.

TA 8.2.6 Summary Comparison of Alternatives

The preceding analysis uses a combination of hydrologic modeling, ecological indicators, temperature thresholds, and robustness/vulnerability assessments to compare management alternatives and their effects on aquatic habitats, native and nonnative fish populations, and ecosystem resilience along the Colorado River from Lake Powell downstream to the international boundaries. A summary matrix of robustness analysis results is provided to depict differences among

alternatives across all issues and indicators (**Figure TA 8-31** and summarized in **Appendix S,** Additional Description of Alternatives).

Figure TA 8-31
Summary of Robustness Results across Issues by Indicator at Reported Thresholds for Each Alternative

Issue	Indicator	Impact Threshold	Alternative[1]: Continued Current Strategy Baseline	No Action	Basic Coordination	Enhanced Coordination	Maximum Operational Flexibility	Supply-Driven (Priority)	Supply-Driven (Pro Rata)	Representative Preferred Alternative
1	**Lake Powell Elevation**									
	Critical Habitat (Colorado River)	Lake Powell is below 3,598 feet ≥70% of months, and Critical Habitat of Colorado Pikeminnow and Razorback Sucker is not inundated in the Colorado River Inflow								
	Critical Habitat (San Juan River)	Lake Powell is below 3,600 feet ≥70% of months, and Critical Habitat of Colorado Pikeminnow and Razorback Sucker is not inundated in the San Juan River Inflow								
	Piute Falls (nonnative barrier)	Lake Powell is below 3,666.5 feet for 100% of months, and the Piute Farms Waterfall remains a barrier to upstream fish passage								
	Smallmouth Bass Entrainment	Lake Powell is above 3,570 feet ≥70% of months, and the risk of smallmouth bass entrainment is reduced								
2	**Water Temperature**									
	Lee's Ferry 20	Number of Days Exceeds 20°C at Lees Ferry (0 days)								
	Little Colorado River 12	Number of Days Exceeds 12°C at the Little Colorado River (≥110 days)								
	Little Colorado River 16	Number of Days Exceeds 16°C at the Little Colorado River (≥110 days)								
	Havasu Creek 12	Number of Days Exceeds 12°C at Havasu Creek (≥110 days)								
	Havasu Creek 16	Number of Days Exceeds 16°C at Havasu Creek (≥110 days)								
	Pearce Ferry 12	Number of Days Exceeds 12°C at Pearce Ferry (≥110 days)								
	Pearce Ferry 16	Number of Days Exceeds 16°C at Pearce Ferry (≥110 days)								
	Smallmouth Bass Population	5-year Smallmouth Bass growth rate (lambda) at Lees Ferry is less than 1								
	Smallmouth Bass Entrainment	Smallmouth Bass entrainment through Glen Canyon Dam is less than 50 individuals								
3	**Lake Mead Elevation**									
	Within Historical Bounds	Lake Mead Elevations Remain Within Historical Bounds experienced from 2008–March 2026, ≥90% of months								
	Pearce Ferry Rapid (nonnative barrier)	Colorado River water levels at Pearce Ferry Rapid are Below 1,090 Feet Above Mean Sea Level, ≥90% of months								
4	**Hoover Dam Releases**	Monthly Releases from Hoover Dam are within the range Observed During 2008–2025, 100% of months								

Percent Futures that Meet Level of Performance: 0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100

[1] Alternative robustness is reported for the full modeling period, except for the Representative Preferred Alternative, for which results are reported for 2027–2039.

Issue 1 assesses the impact of lake elevation on several native fish indicators. One of the greatest threats to native fish and a priority for management agencies would be the establishment of smallmouth bass downstream of Glen Canyon Dam, which becomes more likely with lower lake elevations. Additionally, reservoir elevations below 3,666.5 feet will help to reduce the threat of nonnative fish movement in the San Juan River. Finally, higher lake elevations would inundate Colorado pikeminnow and razorback sucker critical habitat and reduce habitat value for those species. When considering the risk of smallmouth bass entrainment at Glen Canyon Dam, the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform best by maintaining higher elevations and cooler water, reducing the likelihood of entrainment and downstream invasion. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and CCS Comparative Baseline keep lake elevations low enough to maintain the Piute Farms Waterfall as a fish barrier, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives allow for a higher potential of inundation and fish passage. The low Lake Powell elevations produced by the No Action Alternative increase the length of exposed riverine habitat for Colorado pikeminnow and razorback sucker, benefiting these endangered species, while all other alternatives tend to decrease habitat through inundation with higher lake levels. However, this comes at the cost of reduced lake habitat for sportfish, which could negatively impact recreational fishing.

The Representative Preferred Alternative generally performs in the middle of the range of alternatives for Issue 1, showing moderate robustness but not outperforming the top-performing option. Across indicators related to protecting riverine critical habitat in the Colorado and San Juan River inflows, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) consistently performs best, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the least robust because they more frequently produce higher Lake Powell elevations that inundate critical habitat, negatively affecting primary constituent elements such as river channel integrity that is preferred by the endangered Colorado pikeminnow and razorback sucker. The Representative Preferred Alternative performs better in protecting critical habitat than these least robust alternatives but does not achieve the level of robustness observed for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and, in some cases, performs similarly to or slightly below the CCS Comparative Baseline. It also performs less effectively than the Enhanced Coordination and Maximum Operational Flexibility Alternatives in maintaining elevations above 3,570 feet to reduce the risk of smallmouth bass entrainment. Overall, the Representative Preferred Alternative represents a moderate outcome among the alternatives, providing some protection of riverine habitat and fish barriers but remaining vulnerable to both relatively dry and wet hydrologic conditions compared with the strongest-performing alternatives for individual indicators.

Issue 2 assesses several factors and measures that influence nonnative fish populations. The primary threat to native fish populations below Glen Canyon Dam is the invasion of warmwater nonnative fish species such as smallmouth bass. Colder water temperatures and reduced entrainment through Glen Canyon Dam, resulting from higher lake levels, help prevent these populations from establishing and expanding. The Enhanced Coordination and Maximum Operational Flexibility Alternatives generally keep Lake Powell higher and are more likely to maintain cooler water temperatures at Lees Ferry, the Little Colorado River confluence, Havasu Creek, and Pearce Ferry.

The colder water limits smallmouth bass population growth but may also restrict native fish spawning and early life-stage recruitment patterns. These two alternatives also keep smallmouth bass population growth rates (lambda) below 1.0 more consistently than all other alternatives. The No Action Alternative, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), and CCS Comparative Baseline are generally less robust, often failing to maintain preferred temperature and entrainment thresholds, especially under drought scenarios. While warmer water temperatures can benefit native fish growth and recruitment, they also favor nonnative species like smallmouth bass, which increases competition and predation risks. Thus, alternatives that limit the number of days above critical temperature thresholds (Enhanced Coordination and Maximum Operational Flexibility Alternatives) are preferable for controlling nonnative fish, despite trade-offs to native fish reproductive success.

Overall, the Representative Preferred Alternative demonstrates moderate performance relative to the other alternatives across the water temperature indicators. It generally performs better than the No Action Alternative and the CCS Comparative Baseline at maintaining thermally suitable conditions for native fish growth in downstream reaches, but not as strongly as the Enhanced Coordination or Maximum Operational Flexibility Alternatives at maintaining cooler temperature regimes. The Representative Preferred Alternative performs best in indicators associated with sustaining temperatures above 12 °C at downstream locations such as Havasu Creek and Pearce Ferry, which support humpback chub growth. However, it performs less strongly for indicators focused on limiting warmer temperatures that could benefit nonnative species, such as maintaining temperatures below 20 °C at Lees Ferry and limiting conditions favorable for smallmouth bass population growth.

Other factors, such as flow regimes and associated water quality, can also impact the native fish community throughout the Grand Canyon. Dissolved oxygen concentrations downstream of Glen Canyon Dam fluctuate seasonally, largely influenced by reservoir elevation and penstock water quality. Salmonid species, such as trout, are more susceptible to low dissolved oxygen, with optimal concentrations for growth and survival between 6–9 mg/L, and thresholds below 3 mg/L leading to reduced survival and feeding efficiency. Across alternatives, dissolved oxygen levels in wetter years are similar, typically between 7 and 8 mg/L, but decrease and become more variable under drier conditions. Modeling assumptions may overestimate dissolved oxygen during low reservoir elevations for some alternatives, but only the Enhanced Coordination and Maximum Operational Flexibility Alternatives are projected to maintain higher minimum dissolved oxygen concentrations—above 3 and 4 mg/L—in most futures, making them more robust in sustaining adequate dissolved oxygen and protecting fish health during extended droughts and low-flow scenarios.

Issue 3 assesses the alternatives based on their impacts on Lake Mead and tributary inflow and shoreline habitats. The No Action Alternative and CCS Comparative Baseline are most robust in maintaining Lake Mead elevations below 1,090 feet for at least 90 percent of months, helping to prevent upstream movement of nonnative fish by maintaining the fish barrier at Pearce Ferry and preserving the existing native species composition in the Grand Canyon. However, the fish barrier also works against upstream movement by native species such as razorback sucker, flannelmouth sucker, or humpback chub (as examples) into habitats within the Grand Canyon. Furthermore, the Representative Preferred and Basic Coordination Alternatives provide moderate protection for

maintaining the Pearce Ferry fish barrier. In contrast, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both the LB Priority and LB Pro Rata approaches) Alternatives are less protective from a Grand Canyon perspective. These alternatives more frequently allow lake elevations to exceed critical thresholds at Pearce Ferry Rapid, which could enable upstream movement of fish. While this movement may benefit native species, it also increases the risk of nonnative fish expanding upstream into the largely native fish community in the Grand Canyon. The Supply Driven Alternative (LB Pro Rata approach) performs best at maintaining Lake Mead above the historical minimum elevation, which would support greater stability in reservoir fish habitat. Shoreline habitat projections in Lake Mead indicate that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are most likely to maintain conditions similar to those experienced in the recent past, particularly in later modeled decades. If the historical shoreline of Lake Mead is maintained, it can be presumed that native fishes will continue adapting to changing shoreline conditions.

Issue 4 assesses the alternative's effects on water quantity, timing, temperature, and quality released from Hoover Dam into the Lower Colorado River, including MSCP conservation habitats. Most alternatives, including the No Action, Basic Coordination, and Representative Preferred Alternatives and the CCS Comparative Baseline, are more robust in maintaining monthly releases within the historical range observed during the 2007 Interim Guidelines period (2008–2025); thus, supporting stable fish communities and habitat conditions. Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are less robust, with a lower percentage of futures maintaining desirable release patterns. Flow modifications under less robust alternatives may negatively affect backwaters, marshes, and spawning sites for listed species such as razorback sucker and bonytail, and may increase risks from predators like flathead catfish. However, it should be noted that any threshold below 92 percent of months across all traces yields historically observed flows out of Hoover Dam, conditions under which native fish species have persisted. Assuming that fisheries management practices continue as in recent years, all alternatives are expected to result in habitat and population dynamics similar to those experienced during the historical period, compared with modeled futures.

The No Action Alternative and CCS Comparative Baseline are more effective at preserving riverine habitats above Lake Powell and limiting upstream movement of nonnative species. The comparative analysis of alternatives across all issues suggests that the Enhanced Coordination and Maximum Operational Flexibility Alternatives generally perform best in controlling nonnative fish risks and maintaining cooler water temperatures below Glen Canyon Dam. Overall, each alternative presents trade-offs between supporting native endangered species, controlling nonnative fishes, and maintaining recreational sportfish habitats.

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TA 8 Attachment 1

Fish Species Life Histories

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TA 8 Attachment 1. Fish Species Life Histories

Introduction

Historically, the Colorado River from present-day Lake Powell downstream to the Southerly International Boundary (SIB) was a dynamic, seasonally warm, and turbid river, with flows ranging dramatically from approximately 1,000 to 120,000 cubic feet per second. This natural variability created a diverse and productive aquatic ecosystem, supporting a food base rich in organic material and providing suitable habitat for several warmwater native fish species (Miller 1961). However, the construction of major dams, beginning with Hoover Dam in 1935, along with increasing water demand and changing land use practices, fundamentally altered the river's flow patterns, sediment loads, turbidity, salinity, and temperature. The river was segmented into a series of impounded reservoirs separated by regulated stretches of flowing water, each altered from its original state by upstream impoundments. These changes had profound effects on both the aquatic food base and fish communities throughout the Colorado River ecosystem.

One of the most significant impacts of dam construction, particularly with Glen Canyon Dam, was the shift from natural seasonal flow variability to highly regulated daily fluctuations driven by hydropower production. Prior to dam construction, river levels remained relatively stable on hourly and daily timescales. With the advent of hydropower operations, water releases now peak during daylight hours to meet electricity demand and decrease at night, resulting in daily water level changes of 2-3 feet in some locations. This artificial "tidal" cycle has had a detrimental effect on the abundance and diversity of aquatic insects, which are a critical component of the river's food web (Kennedy et al. 2016). Insect eggs laid along the high-water mark are often left exposed and desiccate rapidly when flows recede, leading to reduced insect populations and, in turn, impacting the food availability for sensitive native fish species.

The closure of Glen Canyon Dam in 1963 marked a turning point for the Grand Canyon reach of the Colorado River, which historically experienced wide seasonal water temperature ranges—from 0 degrees Celsius (°C; 32 degrees Fahrenheit [°F]) in winter to nearly 30 °C (86 °F) in late summer and supported a habitat for several warmwater native fish species (Topping et al. 2003; Cole and Kubly 1976). Yet, even under natural conditions, only 8 of the 35 native fish species of the Colorado River were commonly found in this reach, with others confined to tributaries or present only seasonally (Gloss and Coggins 2005). The altered flow regime and cooler, clearer water released from upstream dams further reduced habitat suitability for native fish, while also affecting nutrient cycling and reducing the productivity of the aquatic food base. As a result, the fish community and food web in the Colorado River have been significantly transformed, with ongoing challenges for the persistence of native species and overall ecosystem health.

Native Fish Species

Threatened and Endangered Species

Humpback Chub

The humpback chub (*Gila cypha)* is a medium-sized, long-lived fish species endemic to the Colorado River System. This member of the minnow family attains a length of about 450 millimeters (mm) (17.7 inches), a weight of about 1,000 grams (2.2 pounds), and it may live as long as 40 years (Hendrickson 1993; Valdez and Ryel 1995; Andersen et al. 2010; FWS 2018a). The humpback chub was federally listed as endangered in 1967 and transferred into the protection of the Endangered Species Act (ESA) in 1973. It was reclassified from endangered to threatened on October 18, 2021 (FWS 2021). Critical habitat for the humpback chub includes 379 miles of the Colorado River system (59 *Federal Register* 13374). Within the analysis area, critical habitat includes the Colorado River from Nautaloid Canyon (river mile [RM] 35, river miles downstream from Lees Ferry) to Granite Park (RM 209) (FWS 1994). The lower 8 miles of the Little Colorado River are also critical habitat, but are outside of the analysis area.

In downlisting the humpback chub, the U.S. Fish and Wildlife Service (FWS) evaluated the stressors associated with the listing factors detailed in the species' status assessment (FWS 2018a). These include river flows (Factor A) and predatory, nonnative fish (Factor C) in Upper Basin populations. They also include water temperature (Factor A), food supply (Factor A), and predatory, nonnative fish (Factor C) in the Lower Colorado River Basin (Lower Basin; FWS 2021). Minimizing these threat factors was important for downlisting the species and preventing it from becoming endangered again. However, smallmouth bass present the highest potential impacts on humpback chub because the species can co-occur with humpback chub in certain canyon habitats and is a potential predator across its entire life history (FWS 2018a). Downlisting the species was also possible because a large reproducing aggregation became established in the western Grand Canyon following a decline in the water level of Lake Mead that exposed historical habitat, and because of warmer releases from Glen Canyon Dam due to a lower level in Lake Powell (Rogowski et al. 2018; Van Haverbeke et al. 2017).

Distribution and Abundance

Five populations of humpback chub can be found in the Colorado River Basin: four in the Upper Basin and one in the Lower Basin (FWS 2018a). The Upper Basin populations are in (1) the Colorado River in Cataract Canyon, Utah; (2) the Colorado River in Black Rocks, Colorado; (3) the Colorado River in Westwater Canyon, Utah; and (4) the Green River in Desolation and Gray Canyons, Utah. The population in the Green and Yampa Rivers in Dinosaur National Monument was recently extirpated with an effort to reintroduce and reestablish the species in this area beginning in 2021 (Valdez et al. 2021). The population in the Lower Basin is found in the Colorado River from about 30-Mile Spring (RM 30) downstream to Pearce Ferry Rapid (RM 281) in the Lake Mead inflow (Rogowski et al. 2018 and 2025), in the lower 8 miles of the Little Colorado River to Chute Falls, and from translocations to Havasu Creek and Bright Angel Creek and above Chute Falls (Schelly 2019; FWS 2018a).

Historically, the humpback chub occurred in warm whitewater regions of the Colorado River upstream of present-day Hoover Dam and some larger tributaries in Arizona, Utah, Colorado, and Wyoming. The humpback chub is a specialized derivative of the *Gila robusta* complex that arose in response to the special conditions of large erosive and turbulent Colorado River habitats (Smith et al. 1979). The first description and photographic documentation of the humpback chub ("bony tail") was from an apparent spawning aggregation in 1908 near the mouth of the Little Colorado River near Beamer's Cabin in Grand Canyon (Kolb and Kolb 1914). The species was described in 1945 by Miller (1946) from three partial specimens caught near Bright Angel Creek in the Grand Canyon. The earliest cataloged collections of humpback chub and two congeneric species are from downstream of Lava Cliff Rapid (RM 246) in the 1940s, before the area was inundated by Lake Mead (Miller 1958). These collections consist of 27 specimens archived at the University of Michigan, including 5 humpback chub, 16 bonytail (*Gila elegans*), and 6 roundtail chub (*Gila robusta*); these specimens were described and confirmed morphologically and meristically by Bookstein et al. (1985). Wallis also reported eight juvenile humpback chub from Spencer Creek in 1950 (referenced in Valdez and Ryel 1997).

Following completion of Glen Canyon Dam in 1963, humpback chub were commonly reported in creel census from the Colorado River near Lees Ferry during 1963-1967 (Stone 1964, 1966; Stone and Queenan 1967), but sampling of seven major tributaries (excluding the Lower Colorado River) between Lees Ferry and Lake Mead in 1968 yielded none (Stone and Rathbun 1968). Holden (1973) collected 15 humpback chub in July 1967 and 1 in August 1970 in the Colorado River within a few hundred meters downstream of Glen Canyon Dam. Humpback chub have not been captured within 45 miles of the dam since the late 1970s (Carothers and Minckley 1981), or about the time Lake Powell stratified and cold-water releases began to persist year-round (Stanford and Ward 1991). Humpback chub were probably excluded from the tailwater by cold releases, high dam releases in 1983-1984, and by predation from large rainbow trout (*Oncorhynchus mykiss*) weighing up to 7 kilograms (kg; 15 pounds; Carothers and Brown 1991).

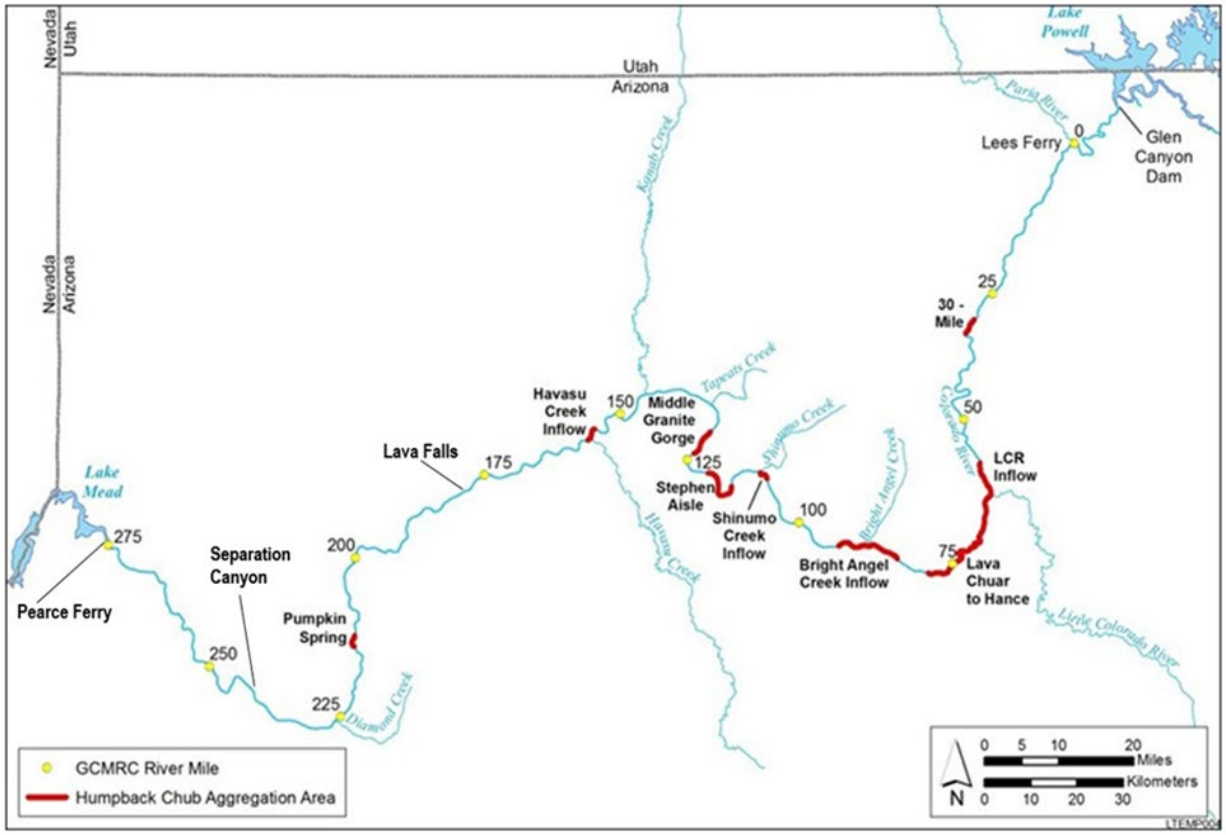
From 1970 through 1976, Suttkus and Clemmer (1977) reported young-of-year (YOY) and juvenile humpback chub between President Harding Rapid (RM 44) and Shinumo Creek (RM 108). Researchers from the Museum of Northern Arizona (Carothers and Minckley 1981) also captured chubs during six river trips in 1977-1979, including adults between North Canyon (RM 20) and Boulder Wash (RM 194) and one juvenile (less than 100 mm total length [TL; 3.9 inches]) just upstream of Granite Rapid (RM 93). Of 19 tributaries sampled from the Paria River (RM 1) to Travertine Creek (RM 230), humpback chub were captured only in the Little Colorado River.

From 1980 through 1981, biologists from the FWS captured 504 adult humpback chub between Nankoweap Canyon (RM 52) and Unkar Rapid (RM 72) (Kaeding and Zimmerman 1983). Fish abundance was reported to resemble a normal or "bell-shaped" distribution with the greatest numbers near the Little Colorado River inflow. Humpback chub smaller than 145 mm (5.7 inches) TL were not caught in the Colorado River upstream of the Little Colorado River inflow, although many small specimens were caught in spring and fall downstream of the inflow, providing the first evidence that post-dam humpback chub reproduction was occurring primarily in the Little Colorado River. From 1984 through 1989, the Arizona Game and Fish Department (AZGFD) (Maddux et al. 1987; Kubly 1990) reported humpback chub in the Colorado River from South Canyon (RM 32) to

RM 217, mostly in or near the Little Colorado River (RM 61). Ninety-six percent of humpback chub captured were between RM 32 and RM 87, and specimens were also captured at the inflows of four tributaries, including Bright Angel, Shinumo, Kanab, and Havasu Creeks, but not in the tributaries.

From 1990 to 1995, Valdez and Ryel (1995, 1997) sampled the Colorado River from Lees Ferry (RM 0) to Diamond Creek (RM 226) and found 5,940 YOY, juvenile, and adult humpback chub in nine aggregations (consistent and disjunct groups of fish with no significant exchange of individuals with other aggregations) (**Figure TA 8 Attachment 1-1**). The largest of these aggregations was associated with the Little Colorado River and included an estimated 3,482 adults that moved from the mainstem to the Little Colorado River in spring for spawning. The second largest aggregation was about 98 adults in Middle Granite Gorge, an area of talus slopes and debris fans, and the smallest aggregations had fewer than 10 fish. These aggregations became the basis for ongoing monitoring of humpback chub in the Grand Canyon (Persons et al. 2016; Rogowski et al. 2018).

Figure TA 8 Attachment 1-1
Humpback chub Aggregation Areas along the Colorado River between Glen Canyon Dam and Lake Mead, and the Area of Western Grand Canyon with the Expanded Population of Humpback Chub



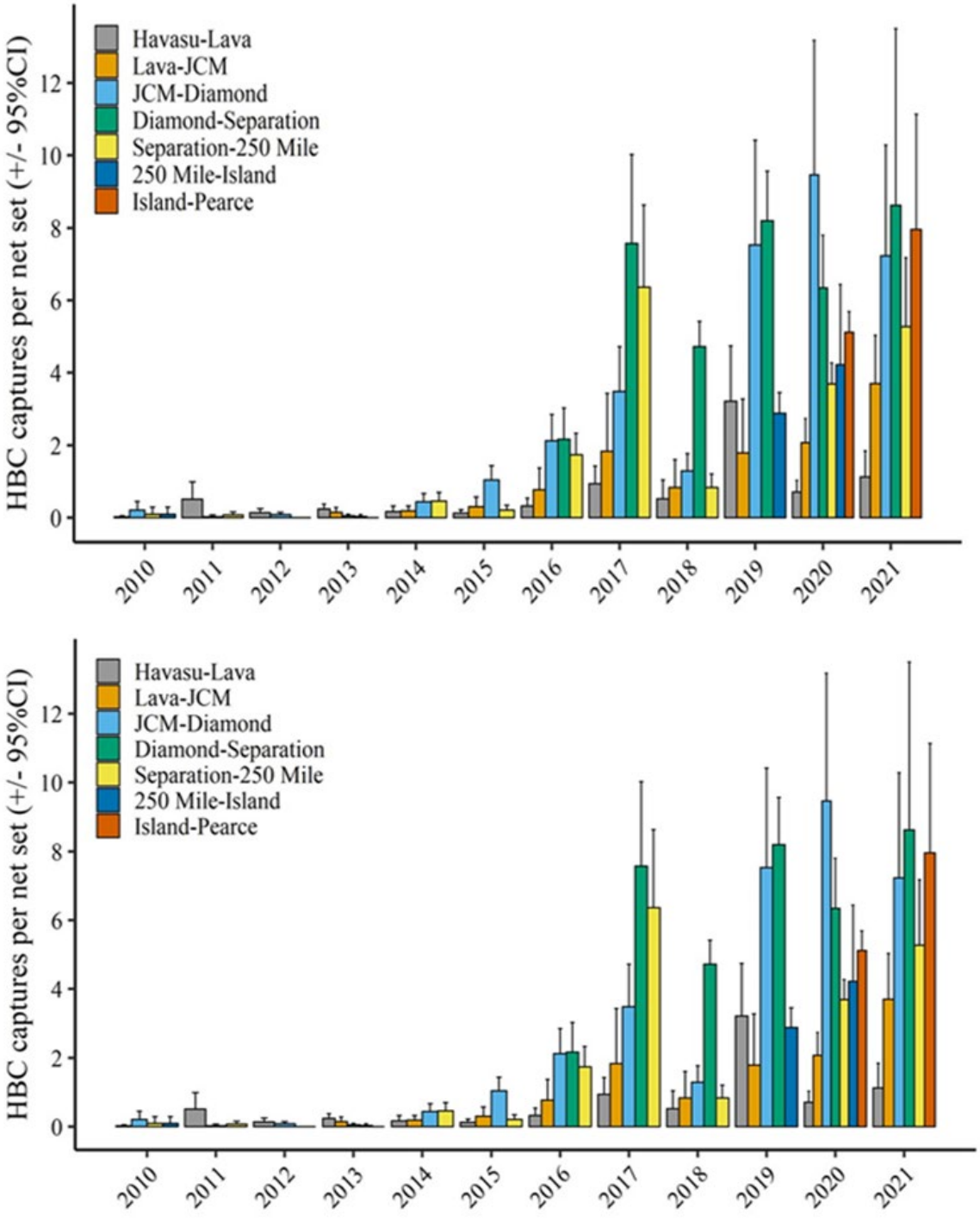
Sources: Valdez and Ryel 1995; Persons et al. 2016; Rogowski et al. 2018

Monitoring humpback chub in the Colorado River through Grand Canyon showed that numbers and distribution in the mainstream river were increasing at a time of warmer water releases from Glen Canyon Dam. In 2015, catch rates of humpback chub downstream of Havasu Rapids began to increase and then tripled starting in 2017 (Van Haverbeke et al. 2017; Dzul et al. 2023) (**Figure TA 8 Attachment 1-2**).

Mark-recapture estimates of adults in the Colorado River in western Grand Canyon (Havasu Rapids to Pearce Ferry) showed an increase in numbers of about 20,000 in 2018 to about 66,000 in 2022 (Dzul et al. 2023; Van Haverbeke et al. 2023) a median adult population abundance of 70 000 (40 000–200 000; 95% credible interval) in 2024 (Dzul et al. 2026) (**Figure TA 8 Attachment 1-3**). Since about 2017, the western Grand Canyon has been populated by humpback chub representing all size classes, with the highest density of adults consistently between Lava Falls and Separation Canyon (RMs 180–240; Dzul et al. 2023). It was unclear if the humpback chub downstream of Havasu Rapids were a new population or an expansion of aggregations found upstream, but recent genetic studies have confirmed humpback chub in the Grand Canyon to be genetically homogenous (Dzul et al. 2025). The humpback chub in the western Grand Canyon now comprises the largest group of humpback chub in the Colorado River System. These numbers compare to about 10,000–15,000 adults in the Little Colorado River/Colorado River aggregation (GCDAMP 2023; Yackulic et al. 2022) and about 4,000 adults for the sum of the four Upper Basin populations (FWS 2018a).

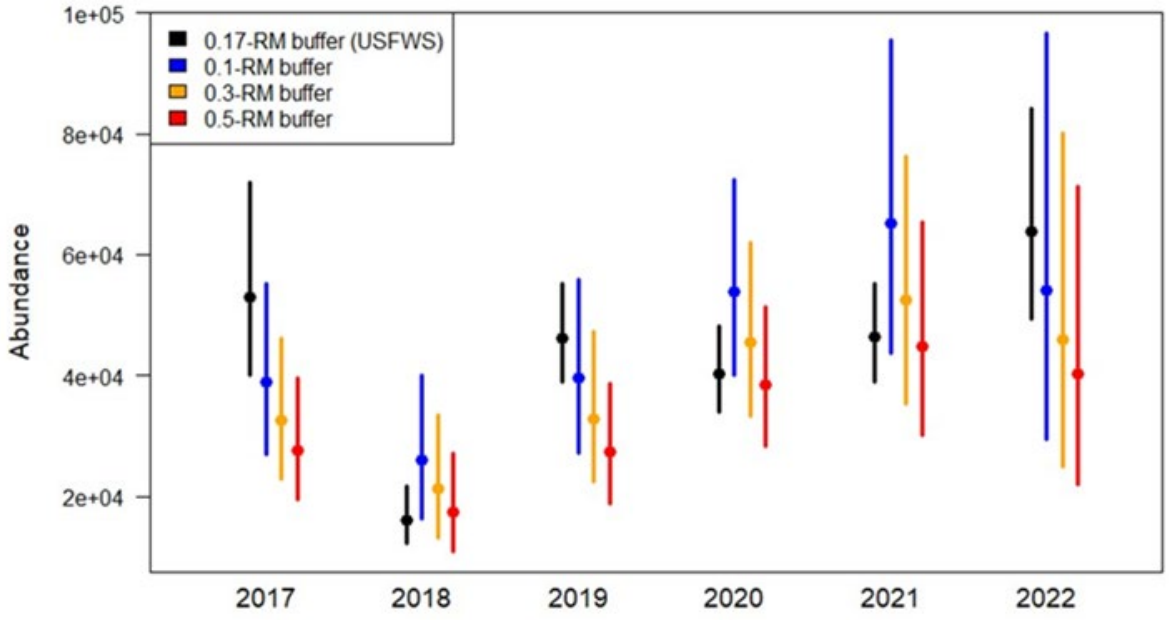
Since 2009, translocations of humpback chub have been made by the FWS to introduce juvenile fish upstream of Chute Falls in the Little Colorado River, and by the National Park Service (NPS) to introduce juveniles into Shinumo, Havasu, and Bright Angel creeks, with the goal of establishing additional spawning populations within the Grand Canyon (Healy et al. 2019; NPS 2013a, 2013b). Survey data from 2013–2015 suggest that translocated humpback chub have successfully spawned in Havasu Creek (Healy et al. 2020; NPS 2013a). Fish translocated to Shinumo Creek were extirpated by a fire and debris flow in August 2014 that scoured the stream channel and displaced or killed most of the fish that were translocated in 2010 (Nelson et al. 2014).

Figure TA 8 Attachment 1-2
Annual Catch-per-unit Efforts of Humpback Chub at Sample Sites Upstream (top) and Downstream (bottom) of Havasu Rapids, 2010–2022



Source: Dzul et al. 2023

Figure TA 8 Attachment 1-3
Abundance Estimates of Humpback Chub in Western Grand Canyon (Havasu Rapids to Pearce Ferry), 2017–2022



Source: Dzul et al. 2023

Habitat

The humpback chub is typically found in canyon-confined, whitewater reaches of large rivers, with adults, juveniles, YOY, and spawning occurring in distinct habitats within those reaches (FWS 2018a). Adults are usually associated with large deep eddy complexes (Tyus and Karp 1990; Valdez and Hoffnagle 1999), talus shorelines, and warm tributaries or springs (Valdez and Ryel 1995). Subadults and juveniles are found at the highest densities along shorelines comprised of vegetation, talus, and large boulders compared to shorelines with bedrock, cobble, or sand (Converse et al. 1998). Juvenile humpback chub along shorelines respond to changing river flows by shifting position to maintain similar habitat conditions of depth, velocity, and cover (Valdez and Ryel 1995; Korman et al. 2004).

Recent studies of an expanding population in western Grand Canyon found humpback chub in open, silt-laden habitats (Boyer et al. 2024), suggesting this species may be able to occupy a wider range of habitats than originally described. This habitat is found in exposed deltaic sediments at the inflow of Lake Mead following a decline in lake elevation. The humpback chub nearshore ecology study collected juvenile humpback chub (under 3 years old) in all types of nearshore habitats, with the highest numbers collected from talus slopes (Dodrill et al. 2015). Prior to about 2017, the largest numbers of young humpback chub in the mainstream river were in and downstream of the mouth of the Little Colorado River, but since then, large numbers of young have been found in the mainstream river, especially downstream of Havasu Rapid to the Lake Mead inflow (Dzul et al.

2023). This indicates that mainstream spawning is occurring and may be widespread with increased water temperatures due to warmer water released from Glen Canyon Dam.

Nearshore habitats are important to humpback chub (and other native fish) because they provide shallow, productive, warm refugia for YOY and juveniles (Reclamation 1995; Hoffnagle 1996). Backwaters are a feature of the mainstream river as sheltered habitat that form at the downstream end of recurrent channels in large eddy complexes and are one objective of high-flow experiments (HFEs; Melis et al. 2011). Temperature differences between the main channel and backwaters can be pronounced in backwaters. The extent of warming is variable and depends on the timing of the daily minimum and maximum flows, the difference between air and water temperatures, and the topography and orientation of the backwater relative to solar insolation (Korman et al. 2006). For example, summertime water temperatures in backwaters have been reported as high as 25 °C (77 degrees Fahrenheit [°F]), while main channel temperatures have been near 10 °C (50 °F) (Maddux et al. 1987), although mainstream temperatures have become warmer in recent decades due to warmwater releases from Glen Canyon Dam.

The amount of warming that occurs in backwaters is affected by daily fluctuations, which drain and fill backwater habitats with cold main channel waters (Valdez 1991; Angradi et al. 1992; Behn et al. 2010). During the low, steady, summer flow experiment conducted in 2000 of about 8,000 cubic feet per second, daytime temperatures in one backwater were as much as 13 °C (23 °F) warmer than in the adjacent main channel; temperature differences were much less at night (Vernieu and Anderson 2013). Backwater temperatures in summer have been reported up to 2–4 °C (3.6–7.2 °F) warmer under steady flows than under fluctuating flows (Hoffnagle 1996; Trammell et al. 2002; Korman et al. 2006; Anderson and Wright 2007). In general, the levels of warming observed in nearshore areas and backwaters during the low summer, steady flows in 2000 persisted only for short periods and were smaller than seasonal changes in water temperatures (Vernieu and Anderson 2013). Consequently, the temperature effects of steady flows on native fish were probably small.

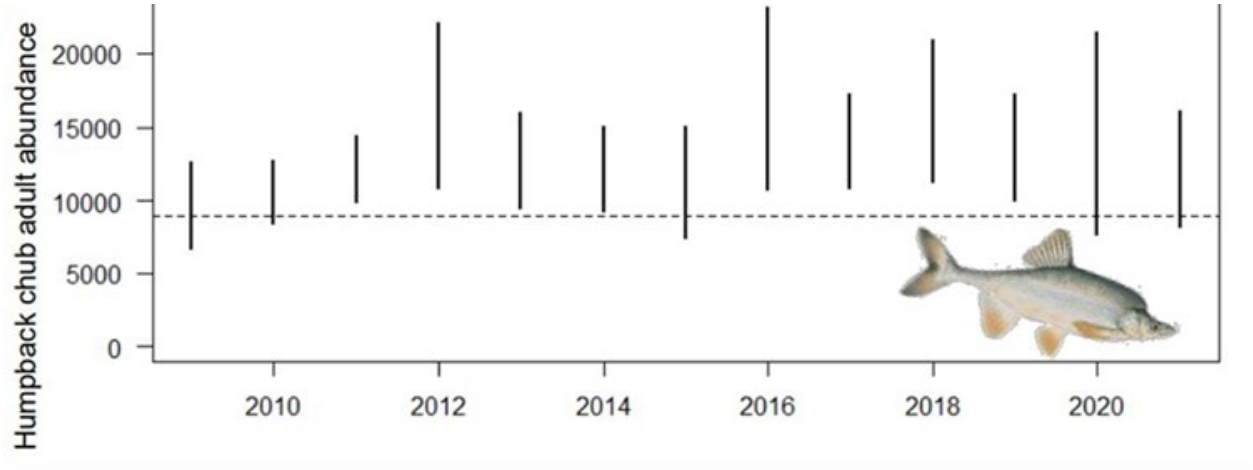
Juvenile humpback chub in the Grand Canyon use backwater habitats when they are available, but the spatial extent of these habitats in the Colorado River is small compared to other nearshore habitats, such as talus slopes. Dodrill et al. (2015) reported that the total abundance of juvenile humpback chub was much higher along talus shorelines than in backwaters, and that when relative densities were extrapolated using estimates of backwater prevalence after an HFE, the majority of juvenile humpback chub were found outside backwaters.

When monitored with radiotelemetry or mark-recapture, adult humpback chub occupied localized habitats and showed little movement from those locations (Valdez and Clemmer 1982; Valdez and Ryel 1995). Radio-tagged adults in Grand Canyon exhibited a high degree of spatial fidelity for specific river locales; mean net movement was 1.49 kilometers (km; range= 0-6.11; 0.9 miles) for 69 radio-tagged fish and 1.64 km (range= 0-99.8; 1 mile) for 238 passive integrated transponders (PIT)-tagged fish (Valdez and Ryel 1997). A separate mark-recapture study reported that approximately 87 percent of recaptured fish were collected in the same mainstream river reach or tributary where they were originally tagged, with 99 percent of all fish recaptured in and around the Little Colorado River (Paukert et al. 2006). Van Haverbeke et al. (2022) reported 288 unique humpback chub detections near the Little Colorado River confluence (RM 60.19–61.53) in 2021. Forty-four additional unique

detections were documented outside of the Little Colorado River confluence. Although most adults have high fidelity to specific river locales, some marked fish have moved as much as 100-154 km (62-102 miles) through the Grand Canyon (Valdez and Ryel 1997; Paukert et al. 2006). This large amount of movement is unique to the Grand Canyon and possibly driven by a need to reach seasonally warmed spawning sites, as radio-tagged fish in the Upper Basin did not exhibit long-range movements with spawning sites nearby (Valdez and Clemmer 1982; Kaeding et al. 1990).

Humpback chub have not been observed spawning in the wild because of the associated high turbidity and deep, turbulent habitats. Where adults have been captured expressing eggs and milt and recently scraped abdomens, the fish were associated with shoreline or mid-channel bars of cobble/gravel substrate with moderate velocity, where females release eggs that are fertilized by an aggregation of multiple males (Valdez 1990; Tyus and Karp 1990; Gorman and Stone 1999). The main spawning area for the humpback chub within the Grand Canyon has been the Little Colorado River, which provides warm temperatures suitable for spawning and shallow, low-velocity pools for larvae (Gorman 1994). Many of the larval fish remain in the Little Colorado River for one or more years, and growth rates and survival are relatively high compared to estimates for the colder waters of the mainstream Colorado River (Dzul et al. 2014; Yackulic et al. 2014). Spring abundance estimates for age-1 humpback chub within the Little Colorado River from 2009 to 2012 ranged from about 1,000 to more than 9,000 individuals (Dzul et al. 2023), and numbers of adults ranged from about 10,000 to 15,000 (**Figure TA 8 Attachment 1-4**). Within the Little Colorado River, young humpback chub prefer shallow, low-velocity, nearshore pools and backwaters; they move to deeper and faster areas with increasing size and age (AZGFD 2001a; Stone and Gorman 2006). In the mainstream Colorado River, YOY fish may be found in backwater and other nearshore, slow-velocity areas that serve as nursery habitats (AZGFD 2001a; Robinson et al. 1998; Valdez and Ryel 1995). Valdez and Masslich (1999) found YOY humpback chub in a warm spring at RM 30, which indicates spawning, about 45 miles downstream of Glen Canyon Dam.

Figure TA 8 Attachment 1-4
Abundance of Adult Humpback Chub that Spawn in the Little Colorado River, 2009–2021



Source: Yackulic 2022; GCDAMP 2023

Life History

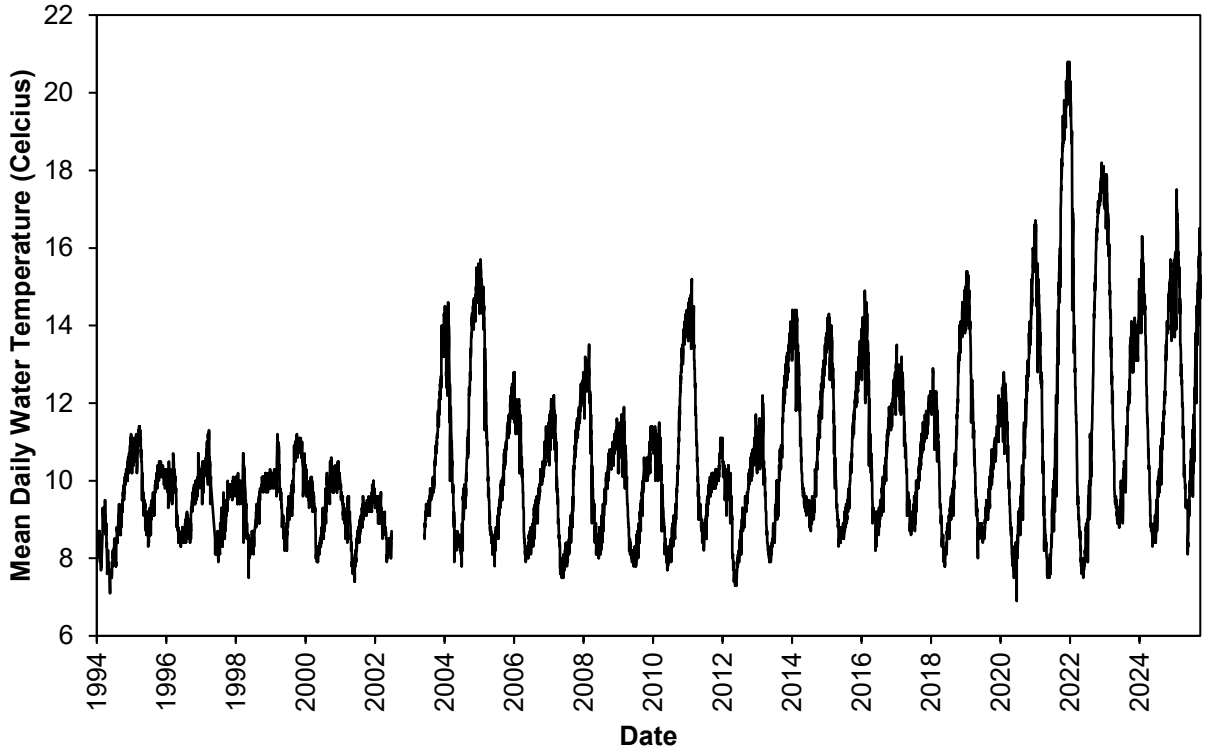
The humpback chub spawns annually in spring, starting at 4-5 years of age, and females broadcast up to 2,500 eggs that are 2-3 mm (0.08 to 0.1 inches) in diameter and are fertilized by multiple males over cobble/gravel substrates. The eggs are semi-adhesive and incubate 4–11 days at 16–22 ºC (60.8-71.6 ºF; Hamman 1982) before hatching into larvae that are 6-7 mm long (0.2 to 0.3 inches; Muth 1990). There is little evidence of long-distance larval drift, as with other native cyprinids such as the Colorado pikeminnow (*Ptychocheilus lucius*), and the larvae are carried passively by currents to nearby sheltered shorelines consisting of boulders, cobble, and gravel (Valdez 1990). The larvae transform to juveniles at 30-40 days of age, to subadults at about 1 year of age, and to adults at 4-5 years of age. There is strong evidence of skipped spawning by humpback chub in the Little Colorado River population, where individuals, especially females, may not spawn every year, possibly due to the need to build up resources prior to spawning in a subsequent year (Pearson et al. 2015).

Although the humpback chub is a warmwater fish species, it persisted in the Colorado River through the Grand Canyon after the construction of Glen Canyon Dam and subsequent cold-water releases. Cold-water temperatures from 1970 to about 2000 provided suitable conditions for the species to persist in the mainstream river as small aggregations but precluded mainstream spawning. Instead, adults of the most proximate aggregation moved annually to spawn in the Little Colorado River, and there was no reproduction in the other aggregations (Valdez and Ryel 1995; Douglas and Marsh 1996). Cold mainstream temperatures limited spawning and growth in the mainstream river but enabled the species to live longer (Yackulic et al. 2014), with better body condition (Meretsky et al. 2000), and low infestations of diseases and parasites (Hoffnagle et al. 2006). Nine aggregations identified by Valdez and Ryel (1995) were mostly associated with warm springs and warm tributary mouths that enabled the species to persist in the mainstream river as juveniles, subadults, and adults, while the largest and only center of reproduction was in the Little Colorado River, from which young fish drifted or moved to the mainstream river.

The Grand Canyon humpback chub population has changed dramatically, starting in about 2004 with warmer dam releases. Humpback chub were mostly unable to reproduce in the mainstream Colorado River because of cold water temperatures, except for local reproduction at 30-Mile Spring (Andersen et al. 2010; Valdez and Masslich 1999). Nearly all reproduction was thought to occur in the lower 8 miles of the Little Colorado River (AZGFD 2001a; Van Haverbeke et al. 2017). Declining reservoir elevations in Lake Powell began in about 2002 (Vernieu et al. 2005; Dibble et al. 2021), leading to warmer releases. Warmer water in the mainstem river allowed for higher juvenile humpback chub survival and growth that likely led to increases in the Little Colorado River population (Finch et al. 2016; Limburg et al. 2013; Yackulic et al. 2014). In western Grand Canyon, warmer water conditions led to reproduction and recruitment in the mainstream (Van Haverbeke et al. 2017), as well as better survival and what is now the largest population of humpback chub in the entire Colorado River system (Dzul et al. 2023). It is notable that in the 1940s, before Lake Mead filled, 5 humpback chub, 16 bonytail, and 6 roundtail chub were captured downstream of Lava Cliff Rapid (Bookstein et al. 1985; Miller 1958), an area that was inundated by Lake Mead for nearly 60 years and is now occupied by this large population of humpback chub following the decline in reservoir elevation and exposure of the original river channel.

The life-history model for humpback chub is mostly known from the Little Colorado River population. Here, adult humpback chub move into the Little Colorado River from the Colorado River to spawn from March to May (Kaeding and Zimmerman 1983; Gorman and Stone 1999; FWS 2018a; Valdez and Ryel 1995). This species requires a minimum temperature of 15.5 °C (60 °F) to reproduce, but mainstream water temperatures typically ranged from 7–12 °C (45–53.6 °F) because of cold releases from Glen Canyon Dam (Andersen et al. 2010). Drought-induced warming and the lower levels of Lake Powell have resulted in mainstream water temperatures consistently exceeding 12 °C (53.6 °F) in summer and fall since 2004. Increased spawning and survival likely played a role in the increase of humpback chub in the Colorado River through the Grand Canyon (Andersen et al. 2010; Coggins and Walters 2009; Yackulic et al. 2014) that led to the rapid and large expansion of humpback chub in western Grand Canyon (Van Haverbeke et al. 2017; Dzul et al. 2023). Rapid growth of small subadults was observed in the mainstream Colorado River near the Little Colorado River during July–October 2021–2023 that corresponded with the warmest water temperatures observed in decades (**Figure TA 8 Attachment 1-5**).

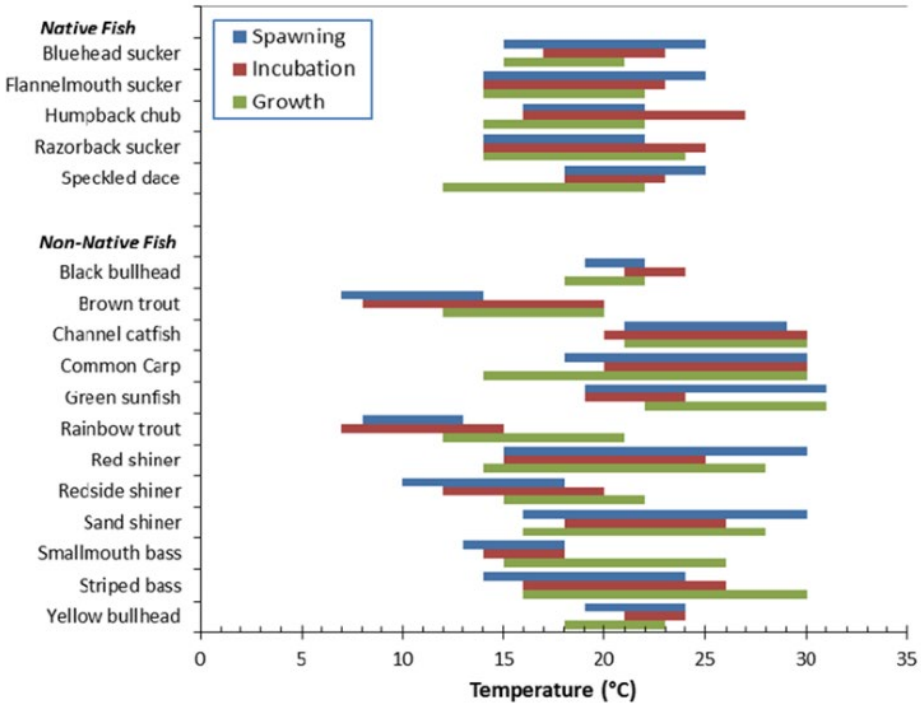
Figure TA 8 Attachment 1-5
Water Temperatures of the Colorado River at Lees Ferry as Measured at United States Geological Survey Gage #09380000, 1995 to Present



Source: USGS 2026
Note: Warmest temperatures of greater than 20 °C (greater than 68 °F) in 2022 were in late September and early October.

In 2022 and 2023, observed river temperatures downstream of the dam were the highest since the filling of Lake Powell; the temperatures were within the range of spawning temperatures for smallmouth bass (*Micropterus dolomieu*), green sunfish (*Lepomis cyanellus)*, and other warmwater nonnative fish (**Figure TA 8 Attachment 1-6**). Smallmouth bass and humpback chub share overlapping temperature preferences for growth, survival, and recruitment. However, prior to 2022, temperatures were sufficient for humpback chub populations to increase while smallmouth bass were relegated primarily to the Lees Ferry sub-reach in low numbers. Evidence of reproduction by smallmouth bass in 2023 raised concerns that smallmouth bass would become established in the Grand Canyon, where they would be likely to prey on humpback chub and other native fish species (Van Haverbeke et al. 2017; Gilbert et al. 2022; Dzul et al. 2023; Smallmouth Bass Ad Hoc Group 2023).

Figure TA 8 Attachment 1-6
Temperature Ranges for Spawning, Egg Incubation, and Growth by Native and Nonnative Fish of the Colorado River System downstream of Glen Canyon Dam



Source: Valdez and Speas 2007

Increased water temperatures can benefit humpback chub growth and survival, but can also allow for the establishment and expansion of warmwater nonnative species, which could result in increased predation on humpback chub (Ward 2011; Yard et al. 2011). Smallmouth bass, green sunfish, and walleye are of greatest concern, but predation by channel catfish (*Ictalurus punctatus)* and black bullhead is also thought to threaten humpback chub in the Grand Canyon, particularly with warmer water conditions (NPS 2013b). Because of their larger size, adult humpback chub are less likely to be preyed on by trout; however, emergent fry, YOY, and juvenile humpback chub in the

mainstream Colorado River in the vicinity of the Little Colorado River are susceptible to predation by trout (Yard et al. 2011).

Under cold-water conditions, predation by rainbow trout and brown trout (*Salmo trutta*) at the Little Colorado River confluence was identified as a mortality source affecting humpback chub survival, reproduction, and recruitment (Valdez and Ryel 1995; Marsh and Douglas 1997; Yard et al. 2011). This may change with warmer mainstream temperatures. Ward and Morton-Starner (2015) conducted laboratory studies that showed predation by rainbow trout on YOY humpback chub decreased from approximately 95 percent to 79 percent as water temperature increased from 10–20 °C (50–68 °F); however, predation success by brown trout was about 98 percent and did not change significantly over the same temperature range. Yard et al. (2011) examined the effects of temperature on trout piscivory in the Colorado River and reported no relationship between water temperature and the incidence of piscivory by rainbow trout, but a significant positive correlation between increased water temperature and the incidence of piscivory by brown trout.

An additional concern for the humpback chub in Grand Canyon is nonnative fish parasites, including the Asian tapeworm (*Bothriocephalus acheilognathi*) and anchor worm (*Lernaea cyprinacea*) that affect the condition and survival of individuals (Clarkson et al. 1997; Hoffnagle et al. 2006; Andersen et al. 2010). While cold-water releases from Glen Canyon Dam have limited reproduction and recruitment of humpback chub (and other native fish) in the mainstream Colorado River, warmer mainstream temperatures over the last two decades have been sufficiently high to allow these parasites to complete their life cycles and expand, as well as other diseases and parasites (Hoffnagle et al. 2006).

Prevailing ecological conditions and water management actions within the Grand Canyon can affect the food base of the humpback chub. The humpback chub is primarily an insectivore, with larvae, juveniles, and adults all feeding on a variety of aquatic insect larvae and adults, including dipterans (primarily chironomids and simuliids), Thysanoptera (thrips), Hymenoptera (ants, wasps, and bees), and amphipods (such as *Gammarus lacustris*) (AZGFD 2001a; Cross et al. 2013; Kaeding and Zimmerman 1983; Valdez and Ryel 1995). Feeding by all life stages may occur throughout the water column, at the water surface, and on the river bottom.

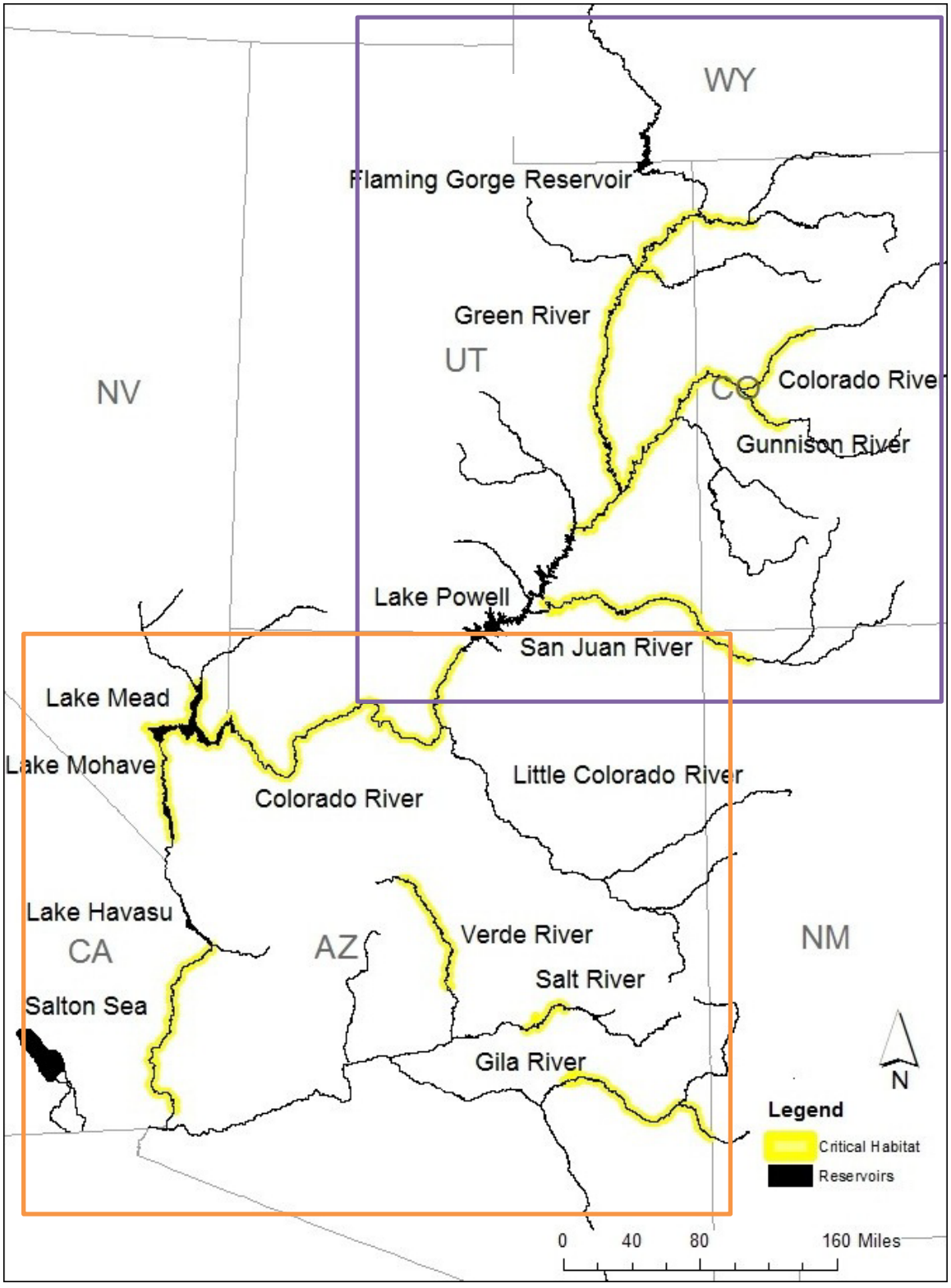
Razorback Sucker

The razorback sucker (*Xyrauchen texanus*) is a large river sucker (Catostomidae) endemic to the Colorado River system. The razorback sucker is one of four endemic Colorado River fishes that Minckley (1973) described as rare in the Lower Basin. It is a large fish that may live more than 50 years, with adults reaching lengths of up to 1,000 mm TL (39 inches) and weights of 5–6 kg (11–13 pounds). However, they are more typically found within the 400–700 mm TL (16–28 inch) range and weigh less than 3 kg (7 pounds; FWS 2018b). Historically, razorback suckers were used extensively as food by native cultures, and populations were commercially harvested as recently as 1949 (FWS 2018b). The razorback sucker was listed as federally endangered in 1991(56 Federal Register 54957) and, more recently, has been included under the auspices of the Lower Colorado River Multi-Species Conservation Program, with the goal of working toward the recovery and persistence of rare fishes in the Lower Basin. A Species Status Assessment (FWS 2018b) found that the status of the razorback sucker has improved, and a Proposed Rule in 2021 (*Federal Register* Vol.

86, No. 127, July 7, 2021) proposed to reclassify the species from endangered to threatened because the *"...species' status has improved due to conservation actions and partnerships, and the threats to the razorback sucker identified at the time of listing in 1991 have been eliminated or reduced to the point that the species is no longer currently in danger of extinction throughout all or a significant portion of its range, but it is still likely to become so within the foreseeable future without current active and intensive management."*

Critical habitat was designated as 2,776 km (1,724 miles) of the Colorado River Basin on March 21, 1994 (59 *Federal Register* 13374). This was composed of 1,519 km (944 miles) in the Upper Basin and 1,255 km (780 miles) in the Lower Basin (**Figure TA 8 Attachment 1-7**). Within the analysis area, critical habitat includes (a) the Colorado River and its historical from Westwater Canyon to full-pool elevation, upstream of North Wash and including the Dirty Devil arm of Lake Powell, (b) the San Juan River and its historical floodplain from the Hogback Diversion to the full-pool elevation at the mouth of Neskahai Canyon on the San Juan arm of Lake Powell, (c) the Colorado River and its historical floodplain from the confluence with the Paria River to Hoover Dam, including Lake Mead to the full-pool elevation, (d) the Colorado River and its historical floodplain from Hoover Dam to Davis Dam, and (e) the Colorado River and its historical floodplain from Parker Dam to Imperial Dam including Imperial Reservoir to the full-pool elevation or historical floodplain, whichever is greater.

Figure TA 8 Attachment 1-7
Critical habitat designated for the razorback sucker in 1994 (yellow highlight), and general areas defined as Upper and Lower Basins (modified from FWS 2018b)



Distribution and Abundance

Razorback sucker are endemic to the Colorado River Basin, which encompasses parts of seven western states, including Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, as well as parts of Sonora and Baja California, the United Mexican States (Mexico). The Upper and Lower Basins are split at Lees Ferry, Arizona, which is 15 miles downstream of Glen Canyon Dam. Glen Canyon Dam provides physical separation between the Upper and Lower Basins. Historically, razorback sucker were widespread and common throughout the larger rivers of the entire Basin, with particularly high razorback sucker abundance in the Lower Basin near Yuma, Arizona. Razorback sucker are thought to have been uncommon in turbulent, canyon-bound reaches, with robust populations typically being found in calm, flatwater river reaches. Historical populations were affected by the construction of multiple in-stream impoundments in the early to mid-1900s, which changed riverine conditions. Razorback suckers have persisted in some resulting reservoirs but have been extirpated in others (Marsh and Minckley 1989; FWS 2018b).

Razorback sucker adults are present and spawning across much of the Colorado River Basin, but some areas have patchy distributions. Species presence is likely due to its ability to utilize both lotic (rapidly moving fresh water, like a river) and lentic (still, fresh water, like a reservoir or lake) environments. Four populations, all maintained by stocking, are currently present in the Upper Basin, including in the Green, Colorado, and San Juan subbasins and Lake Powell. Lower Basin populations currently occur in Lake Mead (and the Colorado River upstream of Lake Mead), Lake Mohave, the Colorado River between Davis and Parker Dams (Lake Havasu), and the Colorado River downstream of Parker Dam, and all except the first are maintained by stocking. Although other, smaller, isolated, and more localized sources of razorback sucker can be found in various ponds, backwaters, and other habitat types common to the Lower Basin, they are not included herein as not all are sampled routinely or with the specific purpose to produce abundance estimates (FWS 2018b), and they are not in the analysis area.

Ten historical records exist for razorback sucker between Glen Canyon Dam and the upper extent of the inflows of Lake Mead between 1944 and 1990 (Valdez and Carothers 1998, FWS 2018b). Razorback sucker were detected in 1990 at the confluence of the Little Colorado River, but they were thought to be functionally extirpated in the Grand Canyon (Clarkson and Childs 2000).

Until recently, the razorback sucker was considered extirpated from the Grand Canyon, with the last individual collected in 1993 at RM 39.3. However, subsequent captures of razorback suckers and flannelmouth-razorback sucker hybrids in the Little Colorado River (Marsh and Douglas 1997) and western Grand Canyon (Bunch et al. 2012; Rogowski and Wolters 2014; Rogowski et al. 2015) indicated the species' continued presence. Notably, four sonic-tagged fish from Lake Mead were detected in Grand Canyon National Park up to Quartermaster Canyon (RM 260) in 2012 (Kegerries and Albrecht 2012), and additional adults were collected near Spencer Creek (RM 246) in 2012 and 2013 (Bunch et al. 2012; GCMRC 2014). Since 2010, studies in the Lake Mead inflow and, since 2014, in the lower Grand Canyon have verified razorback sucker spawning and larval production within Grand Canyon National Park, with larvae documented as far upstream as RM 179 (Albrecht et al. 2014), and in 2019, eight larvae were captured between RM 127.3 and RM 279.0, extending the known upstream distribution by 17.5 RM compared to the previous record (Rogers et al. 2023).

However, no razorback sucker larvae have been detected since 2019, suggesting that spawning in the mainstream river may be limited or no longer occurring.

Although captures of any life stage of razorback sucker are rare in the Grand Canyon, telemetry of translocated razorback sucker has been useful for documenting use and movement since 2014 (Albrecht et al. 2014). Since 2014, six translocated fish have been detected through telemetry above RM 30 (Rogers et al. 2023). Most recently, Roger et al. (2023) reported that a translocated adult razorback sucker was detected via sonic telemetry to have been near RM 15.

The largest reservoir population of razorback sucker, estimated at 75,000 in the 1980s, occurred in Lake Mohave, Arizona and Nevada, but at present, no wild fish remain because of a lack of recruitment (Marsh et al. 2003; Marsh et al. 2005; Marsh et al. 2015). However, Lake Mohave remains an actively managed and important genetic refuge for the species where larvae are collected, reared in the hatchery, and released back into the reservoir at larger sizes to improve survival, as little to no natural recruitment occurs because of predation (Marsh et al. 2015; FWS 2018b). Razorback sucker were also often reported in the riverine Lower Basin downstream of Lake Mohave from the early 1940s through the early 1980s (FWS 2018b), and currently one of the largest populations of this species occurs in the reach between Davis Dam and Parker Dam (LCR MSCP 2024).

The Gila River system encompasses the Verde, Gila, and Salt Rivers and their tributaries. Razorback sucker historically occupied all larger streams in the Gila River Basin, including the Salt, Verde, and Gila Rivers (FWS 2018b). By the 1970s, the species was extirpated from the Basin, and by 1981, efforts to reestablish razorback suckers had begun, but lack of survival precluded additional work in these locations (FWS 2018b).

The decline of the razorback sucker throughout its range has been attributed primarily to habitat loss due to dam construction, the loss of spawning and nursery habitats as a result of diking and dam operations, and alteration of flow hydrology (AZGFD 2002a; FWS 2018b). For example, the 80 percent reduction in the historical distribution of this species has been attributed to the construction of Hoover, Parker, Davis, and Glen Canyon Dams on the Colorado River and Flaming Gorge Dam on the Green River (Mueller et al. 2000). In addition, competition with and predation by nonnative fish have also been identified as important factors in the decline of this species (Minckley et al. 1991; FWS 2002a). In the Grand Canyon, the decline of native fish, including razorback sucker, has been attributed to multiple factors, including modifications to river temperatures and discharge patterns due to Glen Canyon Dam and the subsequent establishment of nonnative fish populations. This has led to more than 2 decades of experimental actions to understand the factors that influence the occurrence, abundance, and distribution of native fish in the Grand Canyon (Coggins et al. 2011; Mueller et al. 2000; FWS 2018b). More recent studies have documented increased native fish abundance throughout the Grand Canyon (e.g., Kegerries et al. 2015 and 2020; Fennell et al. 2024).

Razorback sucker in the Grand Canyon have been observed, and evidence of spawning has been observed in the river from at least Lava Falls through the entirety of Lake Mead, and it maintains a reproducing population in the analysis area (Albrecht et al. 2014; Kegerries et al. 2015). Currently, there is little information on the habitat use and life-history needs of the species in the Grand Canyon and Lake Mead.

Habitat

The razorback sucker uses a variety of habitats, ranging from mainstream channels to slow backwaters of medium and large streams and rivers (AZGFD 2002a; FWS 2018b). In rivers, habitat requirements of adults in spring include deep runs, eddies, backwaters, and flooded off-channel areas; in summer, runs and pools, often in shallow water associated with submerged sandbars; and in winter, low-velocity runs, pools, and eddies. (FWS 2018b). In reservoirs, adults prefer areas with water depths of 1 meter (3.3 feet) or more over sand, mud, or gravel substrates. Young require nursery areas with quiet, warm, shallow water such as tributary mouths, backwaters, and inundated floodplains along rivers, and coves or shorelines in reservoirs (FWS 2018b). Captures of larval razorback sucker in the western Grand Canyon in 2014 and 2019 found the highest density of larvae in isolated pools, which comprised less than 2 percent of all habitats sampled (Albrecht et al. 2014; Kegerries et al. 2019). Similar results were found in 2015, when the highest catch of larval razorback sucker was found in isolated pools, followed by backwaters, which comprised 2.1 percent and 9.1 percent of habitats sampled, respectively (Kegerries et al. 2015). Marsh et al. (2024) provide an exhaustive review of the current concepts related to the role of isolated backwaters and their creation for this species, the need for genetic monitoring, and other pertinent management actions for razorback sucker in the Lower Basin.

Life History

Adults and immature razorback sucker are omnivorous, feeding on algae, zooplankton, and aquatic insect larvae. In Lake Mohave, their diet is dominated by zooplankton, diatoms, filamentous algae, and detritus (Marsh 1987). Razorback suckers exhibit relatively fast growth in the first 5 to 7 years of life, after which growth slows and possibly stops (AZGFD 2002a). Both sexes mature by about age 4. Spawning in rivers occurs over bars of cobble, gravel, and sand substrates during spring runoff at widely ranging flows and at water temperatures typically greater than 14 °C (57 °F) (FWS 2002a, 2018b). In reservoirs, spawning occurs over rocky shoals and shorelines. Temperatures for spawning, egg incubation, and growth of this species range from 14–25 °C (57–77 °F).

Hatching success is temperature dependent, with 100 percent mortality occurring at temperatures less than 10 °C (50 °F); optimum temperatures for adults are around 22–25 °C (72–77 °F) (AZGFD 2002a). Based on back calculation from the dates of larval collection, Kegerries et al. (2015) estimated that the onset of spawning in western Grand Canyon was in mid-February when average daily water temperatures were between 10 °C and 12 °C (50 °F and 53.6 °F). Spawning appeared to peak toward the end of March when water temperatures were in the range of 12–14 °C (54–57 °F), although the entire spawning period was estimated to range from mid-February to July (Kegerries et al. 2015).

Historically, this species exhibited upstream migrations in spring for spawning, although current populations include groups that are sedentary and others that move extensively (Minckley et al. 1991). Adults in the Green River subbasin move as much as 62 miles to specific areas to spawn (Tyus and Karp 1990). In Lake Mohave, individuals move 12-19 miles between spring spawning and summer use areas (Mueller et al. 2000). Kegerries et al. (2015) reported that sonic-tagged razorback suckers moved up to 224 miles within the western Grand Canyon, the Colorado River inflow to Lake Mead, and throughout Lake Mead as a habitat used by all life stages of this species.

Bonytail

The bonytail is a medium-sized fish species endemic to the Colorado River and its tributaries. The species was historically widespread and common from Mexico to Wyoming, but by the 1970s had declined to fewer than 50 known individuals (FWS 2002b). The bonytail was listed as an endangered species in 1980 because of extirpation from most of its range caused by habitat alteration (45 *Federal Register* 27710; April 23, 1980). Critical habitat for the bonytail (59 *Federal Register* 13374, March 21, 1994) includes 502 km (312 miles) of the Colorado River system. Within the analysis area, critical habitat includes (a) the Colorado River from Brown Betty Rapid to Imperial Canyon in the Lake Powell inflow, (b) the Colorado River from Hoover Dam to Davis Dam including Lake Mohave up to its full-pool elevation, and (c) the Colorado River from the northern boundary of Havasu National Wildlife Refuge to Parker Dam including Lake Havasu up to its full-pool elevation. The elevation at Imperial Canyon is 3,680 feet, which is within the full-pool elevation of Lake Powell of 3,700 feet, the defined analysis area of this Final Environmental Impact Statement (EIS).

A Bonytail Recovery Plan was approved in 1990 and amended and supplemented by Recovery Goals in 2002 (FWS 2002b). A Species Status Assessment has not been developed for the bonytail, and the most recent 5-Year Status Review (FWS 2024a) recommended no change in the listing status. The current Recovery Priority Number of 5C is indicative of a species facing a high degree of threat, having a low recovery potential, and is listed at the species level, and there is the potential for conflicts between needed recovery actions and economic activities. The bonytail is included in the Upper Colorado River Recovery Program and the Lower Colorado River Multi-Species Conservation Program. These programs undertake management actions for the conservation of the species, including stocking, flow management, nonnative fish control, and habitat development. Despite management efforts, signs of bonytail survival in the wild remain rare, and the ecology of the species remains poorly understood (Bestgen et al. 2008). Without viable, wild bonytail populations, the species continues to rely on hatchery propagation to persist in the wild and to advance recovery efforts. The present hatchery propagation program is based on a founder population of 11 individuals (6 females and 5 males) taken from Lake Mohave between 1976 and 1978 (FWS 2002b).

Distribution and Abundance

The bonytail was historically widespread and common throughout the larger rivers and tributaries of the Colorado River system, with historical captures documented from Mexico to Wyoming (Behnke and Benson 1980; Minckley and Deacon 1991; Mueller and Marsh 2002; FWS 2002b). The first recorded bonytail from the Upper Basin was in 1889, when one specimen was captured from the Green River. Subsequent historical collections, limited largely to anecdotal and historical interviews with limited scientific documentation, indicate a once-expansive range of bonytail inhabitance (FWS 2002b). During the 1950s, bonytail populations underwent a large but poorly documented decline in abundance following extensive biotic and abiotic habitat modifications, including dam construction, water withdrawal, land use practices, and widespread introductions of nonnative fish (Miller 1961). Holden (1991) described the effects of a large-scale rotenone treatment in the upper Green River and provided insight into the rather large population of bonytail present until 1962, at the time of the treatment. Bonytail numbers were drastically reduced in the Green River following the closure of Flaming Gorge Dam in 1963 (Vanicek and Kramer 1969; Holden and Stalnaker 1975). Very few bonytail have been captured in the Upper Basin since the 1980s, including one from Desolation

Canyon of the Green River during 1979-1981 (Tyus et al. 1982), 14 juveniles and adults from Cataract Canyon during 1985-1988 (Valdez 1990), and one from Black Rocks (Kaeding et al. 1986). These were probably the last wild bonytail captured in the Upper Basin before widespread stocking of hatchery fish (Bestgen et al. 2008).

Bonytail numbers in the Lower Basin followed a similar trend of rapid decline (FWS 2002b). FWS (2002b) summarizes and references historic captures downstream of present-day Lake Powell. In the 1940s, 16 individuals were captured from the Grand Canyon (as referenced in FWS 2002b). In the 1950s, a large aggregation estimated at 500 adults was located spawning over a shelf of angular rock and gravel in Lake Mohave. Because of the low numbers of bonytail seen in the wild, the FWS and its cooperators initiated a program in 1974 to collect the few remaining wild bonytail and establish a broodstock for reintroducing the species and reestablishing wild populations (FWS 2002b). Thirty-four bonytail were captured in Lake Mohave from 1976 to 1988, and 11 of these fish (6 females and 5 males) were used to establish a hatchery broodstock, the progeny were stocked into Lake Mohave and Lake Havasu, as well as in the Upper Basin (Minckley et al. 1989; Minckley et al. 1991; FWS 2002b). From 1981 to 2013, approximately 209,500 bonytail were stocked into Lake Havasu (Humphrey et al. 2014), and from 1991 to the end of 2022, 483,224 bonytail were stocked in the Lower Basin (Marsh et al. 2024). Of these, approximately 98,172 were stocked into Lake Mohave and lakeside backwaters (the mouths of inundated desert washes separated from the reservoir by wind-generated gravel berms), 284,392 into Lake Havasu and adjacent habitats, 99,591 into the mainstream Lower Colorado River and its connectives downstream of Lake Havasu, and 1,069 into inland impoundments and isolated backwaters along the Lower Colorado River. Bonytail stockings into the Lower Colorado River or connected backwaters have produced no evidence of long-term survival, reproduction, or recruitment, while stockings into habitats free of nonnative fishes have demonstrated survival, reproduction, and even recruitment, suggesting that the future of this species may depend on isolated habitats and intensive nonnative fish management (Marsh et al. 2024).

Hatcheries in the Upper Basin produce and stock over 35,000 adult bonytail per year into Upper Basin rivers, including the Green, White, Yampa, Dolores, Gunnison, San Rafael, Price, and Colorado (Integrated Stocking Plan Revision Committee 2015). The hatcheries include Utah's Wahweap Hatchery (Big Water, Utah), the FWS's Ouray Hatcheries (Grand Junction, Colorado and Randlett, Utah), and Colorado's Native Aquatic Species Recovery Facility (Alamosa, Colorado). Bonytail have spawned naturally in ponds at Wahweap State Fish Hatchery, creating an overabundance of fish that exceeds hatchery capacity. Hence, hatchery managers released over 150,000 untagged juvenile bonytail into Lake Powell between 2016 and 2023 in addition to their traditional stocking targets (FWS 2024a).

Two bonytail were captured recently in the Colorado River downstream of Glen Canyon Dam (FWS 2024a). In July 2023, an untagged bonytail was found downstream of the dam in the -12-mile slough. The size of the bonytail indicates it was likely part of a 2023 stocking event from Wahweap that survived in Lake Powell and passed through the dam penstocks. A second bonytail was captured in Glen Canyon in fall of 2023 that was PIT-tagged and released alive. Additional bonytail were detected in Lake Powell. One bonytail was captured in a gill net in Lake Powell in March 2023. When sampling for larval razorback sucker in the Colorado River arm of Lake Powell in 2022, Utah Division of Wildlife Resources biologists found two larval bonytail, indicating that the species

naturally reproduced in the Colorado River inflow area. Finally, Rogers et al. (2024) summarize the capture of a single adult bonytail in good health in Lake Mead near the Las Vegas Wash inflow.

Habitat

Information on bonytail habitat use is limited because of the small numbers of individuals left in the wild and due to the extirpation of this species prior to extensive sampling of the Colorado River (Bestgen et al. 2008; Marsh et al. 2024). Early fisheries surveys indicate that bonytail were found in high gradient, gravel, riverine sections, but this observation is probably based on locations of the last few wild fish captured in the Upper Basin (Bestgen et al. 2008). Bonytail are characterized as being adapted to the swifter sections of the Colorado River, with affinity for areas of high flow and rocky habitat types (Miller 1946). Like other native fishes, backwaters and other slackwater habitats are thought to serve as important nursery areas for young bonytail (FWS 2002b). Available information suggests that adult bonytail display similar habitat affinities to those of other native fishes, with a preference for deep, fast-water sections, as well as eddy and pool habitats. Vanicek (1967) noted bonytail habitat selection coincided with habitats occupied by roundtail chub and found these species not only in pools and eddies near "fast-flowing" riverine areas but also in slower sections. Valdez (1990) reported that wild bonytail used the same habitats as humpback chub, with individuals being found in shoreline eddy habitats, boulders, and cobble, and near swift water sections in Cataract and Desolation canyons. Miller (1946) hypothesized that the unique morphological characteristics of the bonytail (long, slender body, adnate scales, and thin, powerful tail) and the humpback chub (large stabilizing dorsal hump and large falcate fins) made these species uniquely adapted to the swift currents, high turbidity, and high salinity of the Colorado River. A laboratory study by Pimentel and Bulkley (1983) showed that hatchery bonytail, when given the opportunity, selected water with high levels of total dissolved solids. Bonytail can persist in water with total dissolved solids of 4,700 mg/L, the highest tolerance reported for any of the *Gila* species of the Colorado River. However, hatchery-produced bonytail may not exhibit the same habitat selection as wild bonytail. Bestgen et al. (2008) found stocked bonytail occupying nearly all habitat types, including riffles that were thought to be too demanding for this species energetically, and likely an atypical habitat choice.

Bonytail were observed spawning over rocky substrate in a reservoir (FWS 2002b) and likely use similar habitat to spawn in both flowing and standing water (Mueller 2006). In the Lower Basin, documented successful natural reproduction in Cibola High Levee Pond indicates that bonytail spawned on shorelines associated with riprap materials (large-diameter gravel, cobble, and boulder substrates) in water 3–6 feet deep (Mueller et al. 2003). Sonic-telemetry studies have also revealed that adult bonytail prefer interstitial spaces associated with shoreline riprap during daylight hours, whereas open-water areas are more commonly used at night, possibly because of the high clarity associated with the off-channel pond. Individuals spawning in Lake Mohave displayed similar diel habitat shifts where adults were found in deeper habitats during the day, and at dark they formed congregations along shallower shoreline habitats (Mueller and Marsh 2002). Intensive telemetry surveillance showed a high degree of site-specific habitat fidelity, with individually marked bonytail consistently returning to the same cavities within the riprap-type shoreline. Young bonytail were most often associated with areas of dense overhead cover in depths greater than 1 m, and they schooled in warm, shallow areas of an oxbow pond (Mueller et al. 2003; Mueller 2006). These findings suggest that habitat for bonytail should include riprapped shoreline materials, and that

bonytail are a highly cover-affiliated (likely vegetation and/or turbidity) species with one of the few specific habitat preferences that has been well documented.

Life History

The life history of the bonytail is believed to be like that of other closely related chub species that are warmwater spring broadcast spawners. Vanicek and Kramer (1969) documented the last substantial spawning of a wild, riverine population of bonytail in Dinosaur National Monument. Ripe fish were collected from mid-June through early July (1964–1966) in water temperatures around 18 °C (64 °F). Bonytail estimated between 5 and 7 years old were determined to be sexually mature (Vanicek 1967), whereas in controlled hatchery environments, Hamman (1982) found that bonytail began to mature sexually at age 2. Johnston (1999) classified bonytails as being broadcast spawners and suggested that the loss of eddy habitats due to the construction of impoundments probably contributed to the apparent reproductive failure of the bonytail and a closely related species, the humpback chub. Marsh (1985) reported that bonytail eggs are adhesive throughout the incubational period, which is thought to be an adaptive strategy to swift-moving currents of the mainstream Colorado River.

As stated previously, active spawning of a large (approximately 500 individuals) aggregate of bonytail in Lake Mohave was observed spawning over angular rock and gravel substrates near shore and in water up to 30 feet deep. Eggs were described as adhesive, and one individual female contained over 10,000 eggs, suggesting a high level of fecundity, a trait that appears to be typical for Colorado River endemic species (FWS 2002b). Even higher levels of fecundity were found in a hatchery, with individual egg production averaging over 25,000 eggs per female (Hamman 1982). Spawning bonytail in Cibola High Levee Pond were observed using shoreline riprap materials, typically in mid-April, frequently during nighttime hours, and in water temperatures ranging from 20.4–21.6 °C (68.7–70.9 °F) (Mueller et al. 2003).

Bonytail egg survival is highly influenced by incubation temperature. Hamman (1982) found 90 percent survival at water temperatures of 20–21 °C (68–70 °F), 55 percent survival at 16–17 °C (61–63 °F), and only 4 percent survival at temperatures of 12-13 °C (54-55 °F). Incubation periods ranged from 99 hours to nearly 500 hours, depending upon water temperatures. Newly hatched fry averaged 6.8 mm (0.27 inches; Hamman 1982). This research is corroborated by Marsh (1985), who found that bonytail embryos have the highest survival rates at temperatures near 20 °C (68 °F) and indicated that newly hatched larvae averaged 6.0–6.3 mm (0.24 inches) in size. In summary, the literature and hatchery evidence show that strong reproductive output and production of young are key characteristics of this species in the absence of predators.

The bonytail's diet is reportedly comprised of a wide variety of aquatic and terrestrial insects, worms, algae, plankton, and plant debris (Mueller and Marsh 2002). This information corroborated earlier findings by McDonald and Dotson (1960) and Vanicek (1967), who also found that Colorado River chub species (including bonytail) fed omnivorously. More detailed and quantitative descriptions of the bonytail diet, including differences in stomach composition by life stage, are limited. However, bonytail stocked into Cibola High Levee Pond fed omnivorously, with adults consuming algae, vegetative material, small fish, and crayfish (various species), while the young fed near the pond surface, consuming zooplankton and invertebrates. Bonytail appear to be cannibalistic as they were

observed consuming their own gametes, as well as young razorback sucker larvae (Mueller et al. 2003).

Colorado Pikeminnow

The Colorado pikeminnow is the largest freshwater fish endemic to the Colorado River system and is the largest member of the minnow family (Cyprinidae) native to North America. Historically, individuals estimated to weigh over 100 pounds and nearly 6 feet in length were reported from the Lower Basin (Seethaler 1978). The Colorado pikeminnow was included in the 1967 List of Endangered Species (32 *Federal Register* 4001; March 11, 1967) and was encompassed in the protection of the ESA in 1973. A Recovery Plan was first developed in 1978, revised in 1989 (Upper Colorado River Basin Coordinating Committee 1989), and amended and supplemented by Recovery Goals in 2002 (FWS 2002c). The most recent recovery plan was approved in September 2023 (FWS 2023). A Species Status Assessment was completed in March 2020 (FWS 2020). The most recent 5-Year Status Review (FWS 2020) concluded that the Colorado pikeminnow is currently in danger of extinction throughout all its range because of the cumulative effects of threats, despite ongoing activities to address threats throughout the species' current distribution.

Critical habitat was designated in 1994 (*Federal Register* Vol. 59, No. 54, 13374-13399, March 21, 1994) and includes 1,148 miles of the Colorado River system. Within the analysis area, critical habitat includes the Colorado River and its historical floodplain downstream to North Wash near Hite Marina (RM 168; river miles upstream of Lees Ferry), including the Dirty Devil arm of the Lake Powell inflow. It also includes the San Juan River and its historical floodplain downstream to the mouth of Neskahai Canyon. At full-pool elevation (37,00 feet), Lake Powell inundates the lower 34 miles of critical habitat on the Colorado River (Imperial Canyon to North Wash, RM 202-168) and the lower 34 miles on the San Juan River (Clay Hills to Neskahai Canyon). A reservoir elevation below 3,603 feet exposes all critical habitat upstream of North Wash on the Colorado River, and an elevation below 3,600 feet exposes all critical habitat upstream of Neskahai Canyon on the San Juan River. Exposing the river channel through critical habitat may be beneficial to the Colorado pikeminnow, as historic riverine habitat provides the lotic environment preferred by the species. There is no critical habitat designated for Colorado pikeminnow in the Lower Basin.

Distribution and Abundance

Colorado pikeminnow historically occurred throughout the warmwater reaches of the Colorado River system, including the Green, Colorado, and San Juan River subbasins in Wyoming, Colorado, Utah, and New Mexico; downstream through the mainstream Colorado River in Arizona, Nevada, California, and Mexico; and the Gila River subbasin in Arizona and New Mexico. Colorado pikeminnow were largely extirpated from the Lower Basin by the 1960s following extensive dam construction, water development, erosive land use practices, and widespread introductions of nonnative fish (Miller 1961). In the Upper Basin, construction of large dams and diversions was more diffuse, leaving longer reaches of river available for habitat and unimpeded movement. Still, Colorado pikeminnow populations in the Upper Basin occur in contracted ranges and reduced abundances. Biochemical genetics show evidence of multiple stocks of Colorado pikeminnow in tributaries of the Upper Basin, with genetic panmixia indicating constant interchange of genes among the stocks or subpopulations (Morizot et al. 2002). This hypothesis of multiple interconnected stocks is supported by long-distance movements and strong fidelity of adults in

contemporary subpopulations to particular tributaries and reflects the development of powerful selection mechanisms that evolved over thousands of years (Irving and Modde 2000; Tyus 1990). Hence, the contemporary populations in the Green River, Upper Colorado River, and San Juan River subbasins are likely derived from stocks with fidelity to those subbasins but with interchange of individuals.

The Colorado pikeminnow currently consists of three populations in the Upper Basin, including wild self-sustaining populations in the Green River and Upper Colorado River subbasins, and a wild population sustained by annual hatchery stocks in the San Juan River subbasin (FWS 2023). About six million young Colorado pikeminnow were stocked from hatcheries into the San Juan River from 1994 to 2020, where the species is reproducing but with limited recruitment. Colorado pikeminnow are not stocked in the Green River or Upper Colorado River. The most recent estimates of abundance are 429 adults (95 percent confidence interval [CI], 334-561) for the Colorado River, and 885 (95 percent CI, 679-1,171) for the Green River for 2015 and 2018, respectively (FWS 2022, 2023). The most recent estimate for the San Juan River is 214 adults (95 percent CI, 162-320) for 2022, including wild and stocked fish (Schleicher et al. 2023). All ages of fish are naturally produced in the Green River and Upper Colorado River populations, and the fish in the San Juan River consist of a mix of naturally produced fish and stocked fish.

Colorado pikeminnow were likely extirpated from the Lower Basin by the mid-1970s, and during 1981–1990, over 623,000 juveniles were reintroduced into the Salt and Verde Rivers, tributaries of the Gila River subbasin in Arizona (Hendrickson 1993), as a nonessential experimental population under Section 10(j) of the ESA. Survival of these fish was low, with few persisting, and the AZGFD stocked the remaining Colorado pikeminnow from their Bubbling Ponds Hatchery in 2018, with no plans to continue stocking into the future. With low survival of stocked fish and a lack of subsequent captures, this experimental population is considered functionally extirpated (FWS 2020). In a separate effort, the FWS recently assessed the potential recovery viability for Colorado pikeminnow in the Colorado River in the Grand Canyon with the intent of stocking fish experimentally (Dibble et al. 2023), but no further action has been taken.

Colorado pikeminnow have not been documented downstream of Glen Canyon Dam since the mid-1970s (FWS 2020), and the last specimen reported from the Grand Canyon was in 1968 (Behnke and Benson 1980). In the first fish surveys of the Colorado River through Glen Canyon before dam construction, McDonald and Dotson (1960) reported only one immature Colorado pikeminnow, and in post-dam surveys, the species was considered rare (Stone and Rathbun 1968). In Lake Powell, Colorado pikeminnow have been captured in small numbers and occur as extensions of populations in the Upper Colorado River and San Juan River subbasins (FWS 2020).

The diversion channels on Glen Canyon Dam closed in March 1963 and began forming Lake Powell. The reservoir reached a full capacity of 3,700 feet elevation on June 20, 1980, but continued to rise to a maximum level of 3,708.34 feet above sea level on July 14, 1983 (Ferrari 1988). At maximum elevation, the reservoir inundated approximately 187 miles of Glen Canyon and Cataract Canyon. As the reservoir was filling, Colorado pikeminnow were caught occasionally in nets for monitoring the fish in Lake Powell. In the spring of 1980, 45 adult Colorado pikeminnow were captured in the Colorado River inflow near Gypsum Canyon (RM 197) when the reservoir was near

full pool (Gustaveson et al. 1985). Some of these fish were radio tagged and later detected in the Colorado River near Grand Junction, Colorado, over 200 miles upstream (Kaeding and Osmundson 1989).

For the Colorado River inflow to Lake Powell, Valdez (1990) sampled Cataract Canyon from Mineral Bottom to Palmer Canyon (RM 195) in 1984-1989 and found 111 larval and YOY Colorado pikeminnow (3 percent of 4,161 total captured) in the Lake Powell inflow downstream of the Big Drops Rapid in Cataract Canyon. These fish were captured in backwaters that had formed in silty deltaic sediments as Lake Powell was receding. Continued sampling of the inflow from 1990 to 1994 (except for 1992) yielded an additional 219 larval and YOY Colorado pikeminnow (Valdez and Cowdell 1994). In 1986, the Interagency Standardized Monitoring Program began, and through that program, YOY Colorado pikeminnow were sampled in the Upper Basin but did not extend into Cataract Canyon or the Lake Powell inflow. The Colorado River inflow to Lake Powell is sampled as an occasional extension of humpback chub monitoring in Cataract Canyon (sampled in 2021, but no Colorado pikeminnow were reported; Ahrens 2022), and the numbers and distribution of Colorado pikeminnow in the inflow are not unknown.

The San Juan River Basin Recovery Implementation Program was established in 1992 to promote recovery of the endangered Colorado pikeminnow and razorback sucker while allowing water development to continue. Surveys to monitor larval fish have been conducted as part of the San Juan River Basin Recovery Implementation Program since 1998 between RM 147.9 (Shiprock, New Mexico) and RM 2.9 (Clay Hills Crossing, Utah) (Farrington et al. 2023). Small-bodied fish monitoring has been conducted from RM 180.6 (Farmington, New Mexico) downstream to RM 3.1 (Clay Hills Crossing, Utah) (Barkalow and Zeigler 2022).

A large waterfall referred to as the Piute Farms Waterfall formed in the transition zone between the San Juan River and Lake Powell and has served as an impassable upstream barrier to fish since 2001, except once for 2 weeks in late July and mid-August in 2011 (Cathcart et al. 2018). During monitoring conducted from 2002 through 2005, 22 YOY Colorado pikeminnow were collected between Clay Hills and Lake Powell from November 2004 to November 2005 (Golden et al. 2006). In 2005 and 2006, 287 and 256 juvenile Colorado pikeminnow were captured, respectively, with only two collected downstream of the waterfall (Jackson 2006; Elverud and Jackson 2007). Studies of stocked Colorado pikeminnows in the San Juan River from 2002 through 2005 (Golden et al. 2006) collected 22 young between Clay Crossing and Lake Powell from November 2004 to November 2005. These data indicate that in the early 2000s, small numbers of Colorado pikeminnow were present near the waterfall (upstream and downstream) when Lake Powell elevations were below 3,666.5 feet.

In 2015–2017, 24 Colorado pikeminnow were captured downstream of the waterfall; most were subadults except for one adult in 2016 (Cathcart et al. 2018). In 2023, three juveniles were captured in the San Juan River arm of Lake Powell near Piute Canyon (RM -34.1) and Neskahai Canyon (RM ~32.0; Schleicher et al. 2024). Two of the fish had been stocked in McElmo Creek on October 25, 2022, about 10 miles upstream of the confluence with the San Juan River and moved over 110 miles downstream to and past the waterfall, while the third fish was untagged (Schleicher et al. 2024). The San Juan River inflow to Lake Powell, like the Colorado River inflow, is periodically sampled.

Hence, the numbers and abundances of Colorado pikeminnow in these inflows are not known with certainty.

Habitat

Colorado pikeminnow inhabit large warm rivers and tributaries of the Colorado River system and require uninterrupted stream passage for spawning migrations and dispersal of young. The species is adapted to a hydrologic cycle characterized by large spring peaks of snowmelt runoff and low, relatively stable base flows (Bestgen 2018; Elverud et al. 2020). High spring flows create and maintain in-channel habitats and reconnect floodplain and riverine habitats. Through most of the year, juveniles, subadults, and adults use relatively deep, low-velocity pools, large eddies, and deep runs that occur in nearshore areas of main river channels (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995). In spring, Colorado pikeminnow adults use floodplains, flooded tributary mouths, flooded side canyons, and eddies that are available only during high flows (Tyus 1990, 1991; Osmundson et al. 1995). Such environments may be particularly beneficial to Colorado pikeminnow as riverine fish that gather in the floodplain serve as prey for the pikeminnow. Such low-velocity environments also provide resting areas for adults and subadults.

Adults are potadromous (highly migratory within a river basin) and move over 600 miles to rocky canyon-confined spawning areas in summer (late June and July) following spring runoff. Spawning takes place in low-velocity runs less than 1 meter (m) deep on cobble, gravel substrate (Tyus and McAda 1984; Tyus 1985, 1990, 1991; Irving and Modde 2000). After hatching and emerging from the spawning substrate, Colorado pikeminnow larvae drift passively downstream to backwaters in sandy, alluvial regions, where they remain for most of their first year of life (Holden 1977; Tyus and Haines 1991; Muth and Snyder 1995; Bestgen and Hill 2016a).

Colorado pikeminnow larvae occupy in-channel backwaters soon after hatching. The greatest number of larvae occurs in backwaters that are large, warm, deep (average, about 1 foot), and turbid (Tyus and Haines 1991; Bestgen and Hill 2016a). Such backwaters are created when a secondary channel is cut off at the upper end and remains connected to the river at the downstream end. These chute channels are deep and may persist even when discharge levels change dramatically. An optimal river-reach environment for growth and survival of early life stages of Colorado pikeminnow has warm, relatively stable backwaters, warm river channels, and abundant food (Muth et al. 2000). Juveniles and adults use deep, low-velocity eddies, pools, and runs, but move into flooded habitats and bottomlands during spring runoff (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995).

Life History

The Colorado pikeminnow is a large piscivorous minnow that spawns annually in spring, starting at 5-7 years of age and may live up to 50 years (FWS 2020). The species is adapted to warm rivers and requires uninterrupted passage for spawning migration and larval drift, and a hydrologic cycle characterized by large spring peaks of snowmelt runoff and low, relatively stable base flows (Bestgen et al. 2018; Elverud et al. 2020). Adults are potadromous and may move up to 590 miles to and from spawning sites in summer (Tyus and McAda 1984; Tyus 1990; Irving and Modde 2000).

Archaeological remains from several sites along the Lower Colorado River and its tributaries indicate that the species was historically widespread, abundant, and the largest fish in the river (Seethaler 1978; Miller 1955). The largest of six specimens from Catclaw Cave (now inundated by Lake Mohave), dating from AD 1100, was at least 1.7 m long (5.6 feet) (Miller 1955). Early expeditions of the Lower Basin provided the type specimen (Girard 1856) and reports of fish frequently taken near Yuma, Arizona, reaching lengths of 1.2-1.5 m (4-5 feet) (Gilbert and Scofield 1898) and *"…fish would easily weigh 100 lb. (45 kg)"* (Chamberlain 1904). The largest confirmed weights are 27 and 34 pounds for two fish from Lake Mead (Wallis 1951). The largest Colorado pikeminnow recently caught was about 930 mm (36.6 inches) TL from the Upper Colorado River (Elverud et al. 2020), and about 900 mm (35 inches) TL from the Green River (Bestgen et al. 2018); these fish are estimated to weigh 25–27 pounds. Contemporary sizes of adult Colorado pikeminnow are not as large as estimated for historical archaeological specimens and accounts from the Lower Basin, where the species is now extirpated. Growth and size in the Upper Basin appear limited by colder temperatures and a shorter growing season (Kaeding and Osmundson 1989). Bulkley et al. (1981) estimated the thermal preference of juvenile and adult Colorado pikeminnow as 24.6 ºC (76.3 °F) and 25.4 ºC (77.7 °F), respectively. Mean temperature of the Colorado River near Cisco, Utah, from 2006–2023 for July, which is the warmest month, is 23.6 ºC (74.5 °F) (United States [U.S.] Geological Survey Surface-Water Monthly Statistics for Utah), which is slightly below the preferred temperature of Colorado pikeminnow. Young Colorado pikeminnow have very specific streamflow and temperature requirements. Kaeding and Osmundson (1989) correlated lower water temperatures with reduced growth of age-0 Colorado pikeminnow and concluded that fish 45-100 mm (1.8-3.9 inches) TL would not grow at water temperatures below 13 ºC (55 °F).

Spawning of Colorado pikeminnow occurs after spring runoff (typically late June through August) at water temperatures of 18–23 °C (64–73 °F) (Vanicek and Kramer 1969; Hamman 1981). Females are broadcast spawners that attract multiple males to fertilize eggs in the water column. Average fecundity is about 66,000–77,000 eggs/female (Hamman 1986), and females broadcast adhesive eggs over cobble bars where the eggs incubate 90–121 hours at 20–24 °C (68–75 °F) (Hamman 1981; Marsh 1985). The larvae emerge from the substrate after about 5 days and drift up to 125 miles to nursery backwaters where survival is critical to recruitment (Holden 1977; Tyus and Karp 1989; Haines and Tyus 1990; Tyus 1991; Tyus and Haines 1991; Bestgen et al. 1997, 1998; Converse et al. 1999).

Nursery areas consist of ephemeral backwaters and shoreline embayments with little or no current (Tyus and Haines 1991). Bestgen (1996) reported that Colorado pikeminnow larval growth rate declines at water temperatures below 22 ºC (72 °F). As summarized in Valdez (2006 and 2014), spawning begins after spring runoff when water temperatures reach at least 16 °C (60.8 °F), with reproduction often initiated between 16–23°C depending on the river system. Their adhesive eggs are scattered over cobble substrates and incubate in interstitial spaces, with laboratory studies showing highest hatching success at temperatures of 20–24°C and incubation times of 90–121 hours. In the wild, eggs typically incubate for about five days before hatching. The mean size of Colorado pikeminnow larvae is 7.7 mm (0.3 inches) TL, and they transition to juveniles at 35.2 mm (1.4 inches) TL, or at about 60 days of age (Snyder 1981). In the Green and Upper Colorado Rivers, most of the juveniles remain in shallow, warm, productive backwaters through summer, fall, and winter, and are flushed from these habitats with the following spring runoff (Valdez and Cowdell

1994). In the San Juan River, the larvae use zero velocity habitats, including backwaters and embayments, and juveniles remain in available low-velocity habitats (Barkalow and Zeigler 2022).

Adult Colorado pikeminnow are primarily piscivores starting in their first year of life, although they lack jaw, palatine, or vomerine teeth. Instead, they have pharyngeal teeth, which are modified gill rakers that process and masticate swallowed food items passing through their gullet (FWS 2002c). Young Colorado pikeminnow consume zooplankton and midge (chironomid) larvae (Vanicek 1967; Jacobi and Jacobi 1982; Muth and Snyder 1995), and piscivorous juveniles, subadults, and adults eat soft-rayed native and nonnative fish (Osmundson 1999), as well as a variety of insects and animals, including Mormon crickets (*Anabrus migratorius*) (Tyus and Minckley 1988), mice, birds, and rabbits (Beckman 1963).

Special Status Species

In addition to threatened and endangered species, the Colorado River also supports special status fish species that are not currently classified as threatened or endangered but are of conservation concern or have significant ecological importance. These species include flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Pantosteus discobolus*), and speckled dace (*Rhinichthys osculus)*, as described below.

Flannelmouth Sucker

The flannelmouth sucker is a medium to large river sucker (Catostomidae). It has a maximum TL greater than 600 mm (23.6 inches; AZGFD 2001b; Rees et al. 2005). It is a long-lived species that lives up to 30 years (AZGFD 2001b). The flannelmouth sucker is categorized by the International Union for Conservation of Nature (IUCN) as a species of least concern and not a focus of wildlife conservation because it is still plentiful in the wild. The species does not qualify as federally endangered, threatened, or conservation dependent. It is a Bureau of Land Management (BLM)-sensitive species in Utah and Arizona. The flannelmouth sucker is included in the Range-Wide Conservation Agreement and Strategy that has developed and implemented conservation measures in lieu of federal listing (UDWR 2006).

Distribution and Abundance

The flannelmouth sucker is endemic to the Colorado River system. Historically, the species ranged throughout the Colorado River in moderate to large rivers in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming (Bezzerides and Bestgen 2002; Rees et al. 2005). Within the analysis area, flannelmouth sucker are found in Lake Powell mostly in the Colorado River and San Juan River inflows, they are abundant in the Colorado River between Glen Canyon Dam and Pearce Ferry, they are in Lake Mead and in tributary inflows, and they are absent downstream of Hoover Dam except for a small, reintroduced population in the Colorado River downstream of Davis Dam (Mueller and Wydoski 2004). Within the Virgin River, this species may be found in the mainstream river and its tributaries downstream to at least Halfway Wash, with specimens also being captured near the Virgin River inflow of Lake Mead, in lentic habitats (Kegerries et al. 2018; Rogers et al. 2024).

In the Grand Canyon, this species is also found in the mainstream Colorado River and its tributaries, including the Little Colorado and Paria Rivers and Shinumo, Bright Angel, Kanab, and Havasu Creeks (AZGFD 2001b; Bezzerides and Bestgen 2002; Douglas and Marsh 1998; Weiss 1993). In contrast to bluehead sucker, flannelmouth sucker are only found downstream of the barrier falls in Shinumo and Havasu Creeks. During annual monitoring conducted between 2000 and 2022, flannelmouth sucker were present in all reaches of the river between Lees Ferry and the inflow to Lake Mead (Makinster et al. 2010; Fonken et al. 2023). Abundance, across all reaches measured as catch-per-unit-effort, has been increasing since 2000, especially since 2004 (Makinster et al. 2010). However, abundance had been decreasing within the reach between RM 0 and RM 179 since about 2005, while increasing downstream of RM 179. Surveys of the small-bodied and larval fish communities in the western Grand Canyon (Lava Falls to Pearce Ferry) found flannelmouth sucker present in the western Grand Canyon, accounting for over 38 percent of the total larval catch in this area (Albrecht et al. 2014).

Abundance estimates using monitoring data and age-structured mark-recapture models show an increase in the abundance of age-1 (juvenile) and age-4 (adult) flannelmouth suckers in the Grand Canyon between 2000 and 2008 (Wolters et al. 2012). Abundance of age-1 flannelmouth sucker increased from about 2,500 in 2000 to about 10,000 in 2008, while abundance of age 4+ adults increased from about 10,000 to about 25,000 for this same period (Wolters et al. 2012). Other abundance estimates based on electrofishing catch-per-unit-effort for this same time period showed an increase in abundance from less than 1,000 in 2000 to about 12,000 in 2009, while the estimated abundance of age-4+ adults increased from about 2,500 in 2001 to about 31,000 in 2009 (Wolters et al. 2012). Long-term fish monitoring by AZGFD (Rogowski et al. 2018) shows flannelmouth sucker in the Colorado River from Lees Ferry to Pearce Ferry increased slowly in catch-per-unit-effort from 2000 to 2011, followed by a general decline to 2014 and an increase to 2017. Based on flannelmouth sucker recaptures in 2002, Mueller and Wydoski (2004) estimated the Reach 3 population to be 2,286 individuals (95 percent confidence interval 1,847–2,998). From 2006 through 2010, estimates ranged from 1,044–2,171 (Best and Lantow 2012). The relative abundance of adult flannelmouth sucker remained high through 2023 (Rogowski et al. 2023).

Habitat

The flannelmouth sucker is generally found in moderate to large rivers. Adults prefer deep water when not feeding (Rinne and Minckley 1991), while larvae and young are often associated with shallow, slow-moving nearshore areas such as backwaters and shoreline areas of slow runs or pools (AZGFD 2001b; Rees et al. 2005). Although it is a riverine species, the flannelmouth sucker has been collected from the inflow areas of Lake Mead (Rogers et al. 2024). In the Virgin River, both adults and subadults are found in low-velocity, nearshore habitats with large amounts of cover, such as eddies and runs over sandy bottoms. Juveniles and adults may be considered habitat generalists and can be found using pool, run, and eddy habitats.

The flannelmouth sucker has been collected from Flaming Gorge and Fontenelle Reservoirs of the Upper Basin. In the Colorado River in the Grand Canyon, subadults are found in eddies and runs over sand bottoms. In the Little Colorado River, adult and juvenile flannelmouth sucker use low-velocity, nearshore habitats with large amounts of cover during the daylight, and faster, more exposed mid-channel habitats at night (Gorman 1994). Juveniles and adults may be considered

habitat generalists and can be found using pool, run, and eddy habitats. Surveys of larval flannelmouth sucker in western Grand Canyon (from Lava Falls to Pearce Ferry) found the highest abundance of larvae in embayments, isolated pools, backwaters, and other low-velocity habitats (Albrecht et al. 2014).

Life History

The flannelmouth sucker is a spring broadcast spawner, where females release eggs into the water column to be fertilized by multiple males. The semi-adhesive eggs fall into crevices of cobble and gravel substrate where they incubate for about 5 days and emerge as larvae 14-16 mm (0.6 inches) TL. The larvae drift passively downstream into low-velocity nursery areas.

Flannelmouth sucker prefer water temperatures ranging from 10–27 °C (50–80.6 °F) and appear to prefer temperatures of about 26 °C (78.8 °F) (Sublette et al. 1990). Water temperatures reported during spawning activity range from 6–18.5 °C (42.8–65.3 °F) but are usually above 14 °C (57.2 °F) (Bezzerides and Bestgen 2002). In the Lower Basin, flannelmouth sucker typically spawn in March and April (Bezzerides and Bestgen 2002). Water temperature has been suggested as a primary cue for spawning in other parts of this species' range, but it does not appear to provide a spawning cue in the Grand Canyon, where relatively synchronized spawning has been reported among sucker stocks from creeks with different temperature and flow regimes (Weiss 1993; Weiss et al. 1998). In the Paria River, the timing of spawning has been correlated with the receding limb of the hydrograph (Weiss 1993).

In the Grand Canyon, flannelmouth sucker apparently spawn in certain tributaries, and fish may move considerable distances to reach spawning sites (Douglas and Marsh 1998; Weiss et al. 1998; Douglas and Douglas 2000). Tributary spawning in the Grand Canyon may be timed to take advantage of warm, ponded conditions at tributary mouths that occur during high flows in the mainstream Colorado River (Bezzerides and Bestgen 2002). Valdez and Ryel (1995) reported large concentrations of bluehead sucker and flannelmouth sucker in tributary mouths through Grand Canyon in spring as presumed spawning runs.

The body condition of flannelmouth sucker is variable throughout the Grand Canyon, but is greatest at intermediate distances from Glen Canyon Dam, possibly because of the increased number of warmwater tributaries in this reach (Paukert and Rogers 2004). Mean condition peaks during the pre-spawn and spawning periods and is lowest in summer and fall (McKinney et al. 1999; Paukert and Rogers 2004). Sucker condition in September was positively correlated with Glen Canyon discharge during summer (June–August), possibly due to an increased euphotic zone and greater macroinvertebrate abundance observed during higher water flows (Paukert and Rogers 2004).

The flannelmouth sucker is characterized by lower lips that are noticeably bulky with thick and fleshy lobes that it uses to feed along river bottoms and around structures. The species is an omnivorous benthic feeder, foraging on invertebrates, algae, plant seeds, and organic and inorganic debris (Bezzerides and Bestgen 2002; Rees et al. 2005; Seegert et al. 2014). The larvae feed primarily on aquatic invertebrates, crustaceans, and organic debris (Childs et al. 1998). As they become juveniles and adults, their diet shifts and becomes primarily comprised of benthic matter, including organic debris, algae, and aquatic invertebrates (Rees et al. 2005; Seegert et al. 2014).

Bluehead Sucker

The bluehead sucker is a medium-sized river sucker (Catostomidae). Adults may reach 300-450 mm (11.8-17.8 inches) TL in large rivers but may be smaller in tributaries; they may live from 6 to 8 years to as many as 20 years (AZGFD 2003; Bezzerides and Bestgen 2002; Sigler and Sigler 1987). The bluehead sucker is categorized by the IUCN as a species of least concern and not a focus of wildlife conservation because it is still plentiful in the wild. The species does not qualify as federally endangered, threatened, or conservation dependent. It is a BLM-sensitive species in Utah and Arizona. The bluehead sucker is included in the Range-Wide Conservation Agreement and Strategy, which has developed and implemented conservation measures in lieu of federal listing (UDWR 2006).

Distribution and Abundance

The bluehead sucker is native to the Colorado River and its tributaries from Lake Mead upstream into Arizona, Colorado, New Mexico, Utah, and Wyoming. This species is also found in the Snake River (Idaho and Wyoming), the Bear River (Idaho and Utah), and Weber River (Utah and Wyoming) drainages (AZGFD 2003; Bezzerides and Bestgen 2002).

Within the analysis area, bluehead sucker are rare in Lake Powell, common in the Colorado River between Glen Canyon Dam and Pearce Ferry, in tributary inflows in Lake Mead, and absent downstream of Hoover Dam. In the Grand Canyon, the bluehead sucker is found in the mainstream Colorado River and its tributaries, including the Little Colorado River, Clear Creek, Bright Angel Creek, Kanab Creek, and Havasu Creek (AZGFD 2003; NPS 2013b; Ptacek et al. 2005; Rinne and Magana 2002). Prior to 2014, it was also found in Shinumo Creek but was largely displaced from that system by large debris flows (Healy et al. 2014). Annual fish monitoring during 2000—2024 in the Colorado River between Glen Canyon Dam and the inflow to Lake Mead shows the bluehead sucker present throughout the mainstream river (Makinster et al. 2010; Kegerries et al. 2015; Rogers et al. 2024). This species is rare in the upper sections of Grand Canyon National Park because of cold dam releases, and increases in number near the Little Colorado River inflow and downstream with warmer water temperatures (Bunch et al. 2012). Bluehead suckers are found more often in Grand Canyon National Park with warmer dam releases.

Within Lake Mead, the bluehead sucker is found periodically in the Colorado River inflow area in limited numbers. Annual native fish monitoring conducted between 2010 and 2024 at the Colorado River inflow area of Lake Mead has produced a total of four individuals (Rogers et al. 2024; BIO-WEST unpublished data). Most contacts occur within the flowing portions of the Colorado River upstream of Pearce Ferry (Rogers et al. 2023).

Abundance estimates using monitoring data and age-structured mark-recapture models show a high variability in the numbers of bluehead sucker over time and location. The abundance of age-1 (juvenile) bluehead sucker in the Grand Canyon appears to have declined from 1990 to 1995, increased from 1995 to 2003, and then declined through 2009 (Wolters et al. 2012). Similar estimates for age-4 (adult) fish show that abundance began increasing from the late 1990s until 2005 or 2006, after which abundance also declined. The estimated abundance of age-1 bluehead sucker has ranged from 1,000 or fewer to as many as 60,000 fish between 2000 and 2009 (Walters et al. 2012). The estimated abundance of age-4+ adults during this same period ranged from about 5,000 to as many

as 75,000 fish. Relatively high numbers of individuals remain in the Lower Colorado River between Lava Falls Rapid (RM 179) and Lake Mead (Bunch et al. 2012). Bluehead sucker larvae were reported throughout the western Grand Canyon between Lava Falls and Pearce Ferry during larval fish community monitoring throughout the area (Albrecht et al. 2014). In this area, the bluehead sucker was the most abundant species in the larval fish community, comprising almost 40 percent of the total catch. Larval fish sampling from Bright Angel Creek (RM 88.5) downstream to Pearce Ferry reported that approximately 26 percent of the larval fish were bluehead sucker (Rogers et al. 2023). Long-term fish monitoring conducted by AZGFD (Rogowski et al. 2018) indicates that bluehead sucker populations in the Colorado River from Lees Ferry to Pearce Ferry increased in catch-per-unit-effort between 2000 and 2010. After this period of growth, their numbers generally declined, with some year-to-year variability, but then rebounded to previous high levels in 2016 and 2017. More recent data show that the relative abundance of bluehead sucker has exhibited a downward trend with considerable fluctuations through 2022 (Fonken et al. 2023).

Habitat

The bluehead sucker typically inhabits rivers and large streams and may be found in smaller streams and creeks (AZGFD 2003; Sigler and Sigler 1987). Riverine habitats may range from cold (12 °C [53.6 °F]), clear streams to warm (28 °C [82.4 °F]), turbid rivers. Large adults live in deep water (6 to 10 feet), while juveniles use shallower, lower velocity habitats (Bezzerides and Bestgen 2002). In clear streams, bluehead sucker stay in deep pools and eddies during the day and move to shallower habitats (for example, riffles or tributary mouths) to feed at night, while in turbid waters they may use shallow areas throughout the day (AZGFD 2003; Beyers et al. 2001). In the Grand Canyon, larval and young bluehead sucker inhabit backwater areas and other nearshore, low-velocity habitats such as eddies, embayments, and isolated pools (Albrecht et al. 2014; AZGFD 2003; Childs et al. 1998). In Lake Mead, larval and young bluehead suckers inhabit slack water, backwater, and lentic habitats (Kegerries et al. 2015).

Life History

The bluehead sucker is a spring broadcast spawner, where females release eggs into the water column to be fertilized by multiple males. The semi-adhesive eggs fall into crevices of cobble and gravel substrate where they incubate for about 5 days and emerge as larvae 12-14 mm (0.5-0.6 inches) TL. The larvae drift passively downstream into low-velocity nursery areas. This species has been reported to be as large as 500 mm (19.6 inches) TL in the mainstream Colorado River in Grand Canyon, with tributary fish being smaller (AZGFD 2003; Valdez and Ryel 1995; Walters et al. 2012). A related subspecies, the Zuni bluehead sucker, occurs in the headwaters of the Little Colorado River along with the bluehead sucker that is the same subspecies as in the mainstream Colorado River (AZGFD 2002b).

Bluehead sucker spawn in spring and summer after water temperatures exceed 16 °C (60.8 °F). Valdez and Ryel (1995) reported large concentrations of bluehead sucker and flannelmouth sucker in tributary mouths through Grand Canyon in spring as presumed spawning runs. Spawning in Grand Canyon tributaries occurs mid-March through June in water depths ranging from a few inches to more than 3 feet and at temperatures of 16–20 °C (60.8–68 °F) over gravel-sand and gravel-cobble substrates (AZGFD 2003; NPS 2013b). In Kanab Creek, spawning has been reported to occur at temperatures of 18.2–24.6 °C (64.8–76.3 °F) (Maddux and Kepner 1988). Smaller tributaries may

provide nursery areas for populations of large adjacent rivers (Rinne and Magana 2002). In Lake Mead, larvae have been captured at temperatures of 18.2–24.6 °C (64.8–76.3 °F) at the Colorado River inflow monitoring site (Kegerries et al. 2015).

The bluehead sucker is an omnivorous benthic forager with a modified lower cartilaginous jaw used as a scraping radula. It feeds by scraping diatoms, detritus, algae, invertebrates, and other organic and inorganic material off rocks and other hard surfaces (Ptacek et al. 2005). Larvae drift to backwaters and other areas of low current, where they feed on diatoms, zooplankton, and dipteran larvae.

Speckled Dace

The speckled dace is native to the western U.S. and is one of eight species in the genus *Rhinichthys*. It is a small fish, typically less than 76 mm (3.0 inches) TL, and has a relatively short lifespan of about 3 years (Sigler and Sigler 1987). The speckled dace is categorized by the IUCN as a species of least concern and not a focus of wildlife conservation because it is still plentiful in the wild. The species does not qualify as federally endangered, threatened, or conservation dependent. It is a BLM-sensitive species in Arizona. Possession or importation of *Rhinichthys osculus* is prohibited or regulated in Colorado and Nevada.

Distribution and Abundance

The speckled dace is the most ubiquitous fish in the western U.S., ranging from the Columbia River drainage (north to southern British Columbia) to the southern Gila River drainage of Arizona and Sonora, Mexico (FWS 2024a). The speckled dace is native to the western U.S. and is one of eight species in the genus *Rhinichthys*.

Although this species is the most widely distributed and abundant native fish species in the Grand Canyon ecosystem, its abundance and distribution could be affected by many of the same factors that affect the abundance and distribution of the other native fish in the ecosystem, namely altered temperature, flow, and sediment regimes and predation by nonnative fish (AZGFD 2002c; Gloss and Coggins 2005).

Within the analysis area, speckled dace are commonly found along shorelines in Lake Powell as well as in the inflows of the Colorado and San Juan Rivers. They are abundant in the Colorado River between Glen Canyon Dam and Pearce Ferry and are also present in Lake Mead and its tributary inflows. Downstream of Hoover Dam, speckled dace occur in smaller numbers. In the Grand Canyon, this species inhabits both the mainstream Colorado River and its tributaries, including the Little Colorado River (Makinster et al. 2010; Robinson et al. 1995; Ward and Persons 2006). Long-term fish monitoring of the Colorado River downstream of Glen Canyon Dam since 2000 shows the speckled dace is the third most common fish species (and most common native species) in the river between Glen Canyon Dam and the Lake Mead inflow, and it was captured most commonly in the western Grand Canyon and the inflow to Lake Mead (Makinster et al. 2010). More recently, Rogers et al. (2024) showed speckled dace were the second most common native species since 2014.

Within the Virgin River, this species occurs within the mainstream and its tributaries, including the Beaver Dam Wash Creek (Kegerries et al. 2018). Long-term fish monitoring of the Virgin River

since 1996 shows the speckled dace to be the third most common fish species (and most common native species) in the lower Virgin River (Kegerries et al. 2018).

Habitat

The speckled dace is found in a variety of habitats, including large rivers, cold, fast-flowing mountain streams, ponds, and warm intermittent desert streams and springs (FWS 2024a). It occurs in rocky runs, riffles, and pools of headwater streams, creeks, and small to medium rivers, typically in waters with depths less than 1.6 feet (AZGFD 2002c), and it rarely occurs in lakes (Page and Burr 1991). Valdez and Ryel (1995) reported finding speckled dace in gravel/cobble fans at arroyos and side canyons of the Colorado River through Marble and Grand Canyons.

Life History

The speckled dace is a small, short-lived minnow that spawns in spring. Adults mature at 2 years of age and are 100-130 mm (3.9-5.1 inches) TL. Spawning occurs in spring when a single female broadcasts 200-500 adhesive eggs over the gravel stream bed, and the eggs are fertilized by multiple males. Speckled dace are omnivorous, feeding on filamentous algae and other plant material, insect larvae and other invertebrates, as well as fish eggs (Seegert et al. 2014). Its young are mid-water plankton feeders (Sigler and Sigler 1987). Speckled dace can spawn twice a year, once in spring and again in late summer when water temperatures are 21–29 ºC (69.8-24.2 ºF; AZGFD 2002c).

High-Risk Nonnative Fish Species

Nonnative fish species have been established in the Colorado River by various means for over a century. Starting in the mid to late 1800s, federal and state agencies distributed nonnative common carp (*Cyprinus carpio*) and channel catfish to rural communities along the Colorado River as a food source. Then, with dam construction in the early 1900s, state agencies began to introduce a variety of warmwater and cold-water species for recreational sports fisheries and as forage to support those fisheries. Changes in flow, temperature, sediment, turbidity, salinity, and physical and biological habitat components altered the river's ecological functions and the collective fish communities (Miller 1961). Understanding the past and present condition and status of fish in the analysis area of this Final EIS is essential to understanding the potential impacts of proposed actions. The following are descriptions of nonnative fish species found in the analysis area.

Rainbow Trout

The rainbow trout is a member of the Salmonidae family, and the life history of this species is extremely variable, depending on location, environmental conditions, and genetic strain (Scott and Crossman 1973). It is one of the most popular and widespread cold-water fish in North America. It is native to cold-water tributaries of the Pacific Ocean in North America and is extensively cultured in hatcheries for stocking as a sportfish throughout the U.S. Angling for rainbow trout is regulated by state game and fish agencies that limit the number of fish taken daily. It is the main sportfish in the 15-mile Lees Ferry sub-reach designated by the AZGFD as a Blue-Ribbon Rainbow Trout Fishery. The species can attain lengths ranging from 30 to 60 cm (centimeters; 12 to 24 inches) and can reach weights of 1.5 to 3 kg (3.3 to 6.6 pounds), although larger individuals have been recorded.

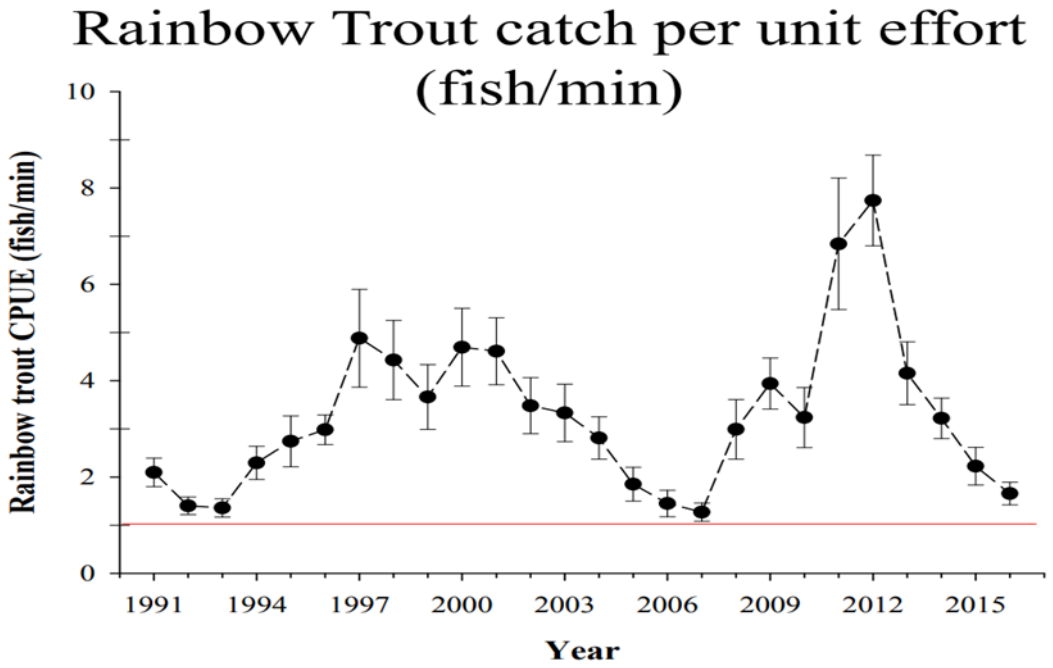
Distribution and Abundance

The rainbow trout was originally introduced into tributaries of the Grand Canyon in 1920-1940 by NPS, including Bright Angel Creek, Tapeats Creek, Havasu Creek, Clear Creek, and Phantom Creek (Runge et al. 2018). With the completion of Glen Canyon Dam in 1963 and the filling of Lake Powell, hypolimnetic dam releases provided a cold, clear, and productive environment for trout in the tailwater. The AZGFD, in cooperation with NPS, began to stock cold-water species in the Lees Ferry sub-reach to establish a recreational fishery. Rainbow trout were stocked in this reach in 1964–1998, and the fish survived successfully, but high fluctuating dam releases precluded most natural reproduction. In 1991, dam operating criteria were modified to increase minimum flows and reduce daily variability in discharge associated with hydropower production. These changes in dam operation allowed the rainbow trout to reproduce and recruit naturally, and stocking the species in the Lees Ferry sub-reach ceased in 1998. Except for localized spawning in and near the confluence of some downstream tributaries (for example, Nankoweap, Clear, Bright Angel, Shinumo, Tapeats, Deer, and Havasu Creeks), most rainbow trout reproduction in the mainstem Colorado River downstream of Glen Canyon Dam occurs within the Lees Ferry sub-reach. Rainbow trout have also been stocked into Lake Mead, Lake Mohave, and Reach 3 of the Lower Colorado River.

Rainbow trout recruitment and population size within the Lees Ferry sub-reach appear to be largely driven by dam operations (McKinney et al. 1999; McKinney et al. 2001; Makinster et al. 2011; Wright and Kennedy 2011; Korman et al. 2011; Korman et al. 2012). The decline in abundance observed in rainbow trout from 2001 to 2007 (**Figure TA 8 Attachment 1-8**) was attributed to the combined influence of increased trout metabolic demands due to warmer water releases from Glen Canyon Dam, together with a static or declining food base, periodic dissolved oxygen deficiencies, and high numbers of the invasive New Zealand mud snail (*Potamopyrgus antipodarum)* serve as a poor food source for fish (Cross et al. 2011).

From 2008 through 2010, the relative abundance of rainbow trout in the Lees Ferry sub-reach increased to near historic high levels (**Figure TA 8 Attachment 1-8**). The highest catch rates in 2011 and 2012 were likely because of warmer releases from Glen Canyon Dam and an input of nutrients from a changed reservoir elevation of Lake Powell (Rogowski et al. 2023). This was after a fall steady flow experiment and equalization flows in 2011 that boosted food base production in the Lees Ferry sub-reach and contributed to greater growth and an increase in abundance of rainbow trout. The population declined tenfold by 2016 due to a combination of lower recruitment and reduced survival of larger trout, which were likely driven by changes in nutrients and invertebrate prey availability (Yard et al. 2023). Survival rates for trout 8.8 inches or longer in 2014, 2015, and 2016 were 11 percent, 21 percent, and 22 percent, respectively, lower than average survival rates between 2012 and 2013. Abundance would have been threefold to fivefold higher had survival rates for larger trout remained at the elevated levels estimated for 2012 and 2013.

Figure TA 8 Attachment 1-8
Mean (±2 Standard Error) Electrofishing Catch Rates of Rainbow Trout in the Glen Canyon Reach, 1991–2016



Source: Rogowski et al. 2023.

Growth declined between 2012 and 2014 due to reduced prey availability, which led to poor fish condition by fall of 2014 (approximately 0.9–0.95, fish condition). Poor condition in turn resulted in low survival rates of larger fish during the fall of 2014 and winter of 2015, which contributed to the population collapse. Korman et al. (2012) found that recruitment of rainbow trout in Lees Ferry was positively and strongly correlated with annual flow volume and reduced hourly flow variation, and that recruitment increased after two of three high-flow releases related to implementation of equalization flows. In Glen Canyon, large recruitment events driven by high flows can lead to increases in the population that cannot be sustained due to limitations in prey supply. In the absence of the ability to regulate prey supply, flows that reduce the probability of large recruitment events can be used to avoid boom-and-bust population cycles (Korman et al. 2017).

Habitat

Adult rainbow trout in streams typically use deep pools, eddies, runs, and overhanging banks for resting, and they feed in open riffles. Juveniles use shallow habitats with in-stream and overhead cover, with recently hatched fry using shallow shorelines (Sigler and Sigler 1996). In the Lees Ferry reach of Grand Canyon, Korman et al. (2011) found the proportion of the age-0 population in low-angle shorelines, which are potentially more sensitive to flow variability, declined from 70 percent in June to 20 percent in November as fish grew and made an ontogenetic habitat shift to deeper habitat, often along steep angle shorelines, which were less sensitive to flow variability. This study

demonstrated how flow variability from daily hydropower production can affect age-0 rainbow trout along low-angle shorelines.

Life History

The rainbow trout can reach a maximum size of nearly 50 pounds and typically matures between 3 to 5 years, with females producing 500-3,161 eggs in streams and 935-4,578 eggs in lakes (Sigler and Sigler 1996). Females prepare individual nests or redds in gravel riffles or runs where they deposit eggs that are fertilized by multiple males. Spawning typically takes place in spring at 10–15 ºC (50-59 ºF), although spawning in the Colorado River downstream of Glen Canyon Dam can occur as early as November and as late as June, with a peak in redd counts from late February to early March (Avery et al. 2015). A strong seasonal pattern in relative condition was seen for rainbow trout in Lees Ferry and was driven by seasonal changes in growth in length and weight (Yard et al. 2015). Body condition was usually at a minimum in January and increased rapidly in spring to attain a peak by July. The decline in condition from July to September was relatively small in clear conditions compared with the other reaches influenced by high levels of turbidity (Korman et al. 2016).

The rainbow trout has a variable diet and will forage throughout the water column on various items (Sigler and Sigler 1996), depending on the fish's genetic strain. In general, the fish's diet changes with the seasons, and generally the species forages near the bottom or near structure (Scott and Crossman 1973). In smaller lake systems, rainbow trout are primarily insectivorous, foraging on Dipetera (e.g., chironomids), Ephemoptera (mayflies), Plecoptera (stoneflies), Crustacea (e.g., amphipods such as *Gammarus* sp.), etc. (Scott and Crossman 1973).

Brown Trout

The brown trout is native to Europe, North Africa, and Western Asia, and it has been introduced as a sportfish into streams, rivers, and lakes around the world. The species was first imported into the U.S. from Germany in 1883 by the U.S. Fish Commission (Mather 1889). Since then, the species has been stocked in virtually every state of the country, including the seven states of the Colorado River system. It was first introduced into Grand Canyon National Park in 1919 by NPS to provide recreational fishing opportunities for park visitors (Runge et al. 2018). Brown trout were introduced into Shinumo Creek, Garden Creek, and Bright Angel Creek in the 1920s and 1930s (Carothers and Minckley 1981), and they were last stocked in the Grand Canyon in Bright Angel Creek in December of 1934, where a reproducing population became established (Runge et al. 2018).

The brown trout is one of four nonnative fish species in Glen Canyon National Recreation Area (NRA) and Grand Canyon National Park identified by NPS as a species presenting a "(1) Very High" level of threat to native fish populations (NPS 2021). The other species with this threat level include smallmouth bass, walleye, and flathead catfish (*Pylodictis olivaris)*. With warmer releases from Glen Canyon Dam as seen in 2004, brown trout can disperse and pose a potential threat to rainbow trout in the Lees Ferry reach and to humpback chub in downstream aggregations (Runge et al. 2018).

Distribution and Abundance

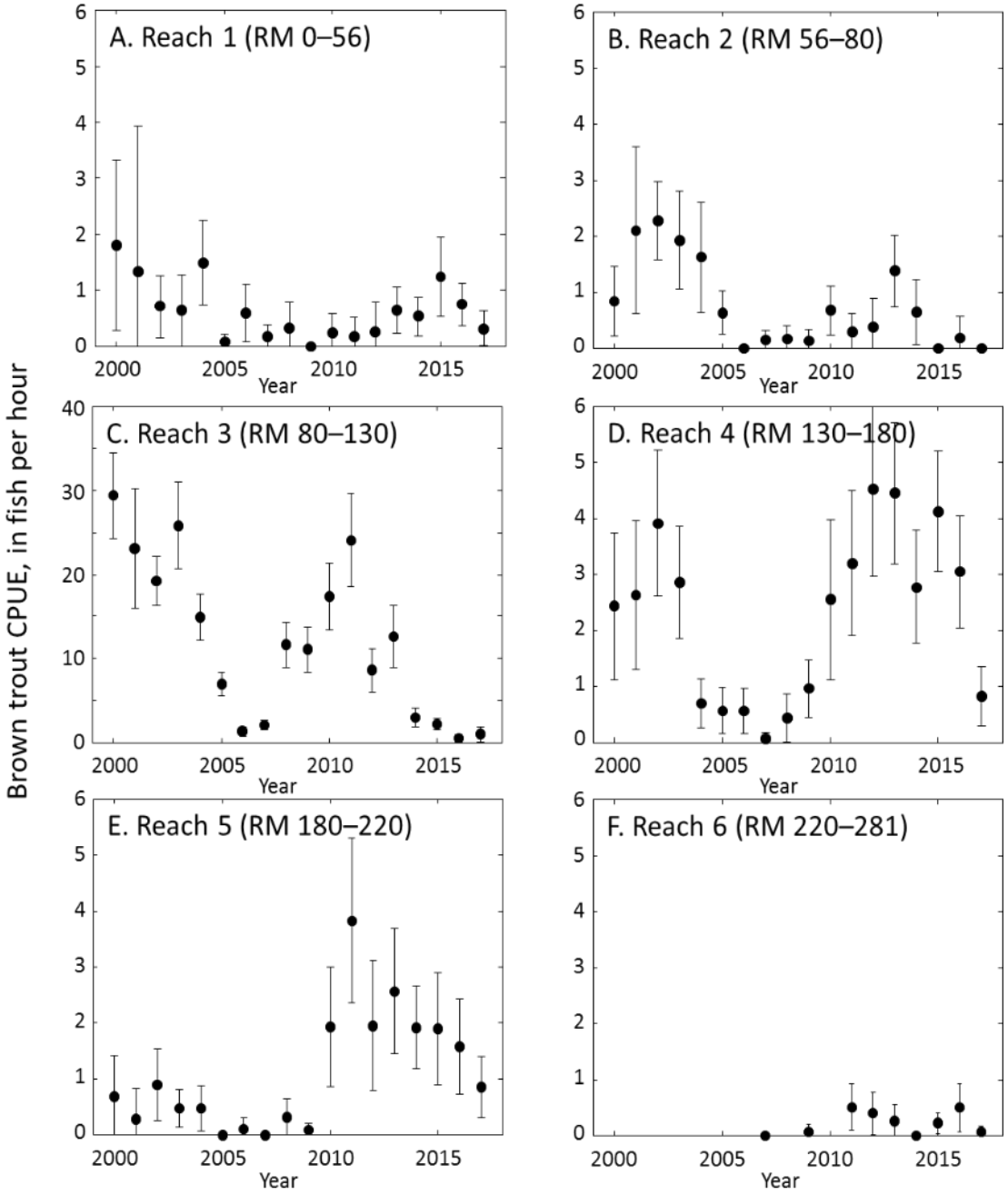
As with rainbow trout, brown trout are not native to the Colorado River and were stocked in Grand Canyon in the first half of the 1900s. Brown trout are no longer stocked in the Colorado River downstream of Glen Canyon Dam and are now found primarily in Lees Ferry and in and near Bright Angel Creek, which supports a naturally spawning population (Reclamation 2011).

Electrofishing catch rates of brown trout have been monitored annually starting in 2000 in six reaches of the Colorado River from Lees Ferry (RM 0) to Pearce Ferry (RM 281) (**Figure TA 8 Attachment 1-9**). Catch rates in most reaches declined from 2000 to 2006 and then increased to the highest levels in 2011–2013 (Makinster et al. 2010; **Figure TA 8 Attachment 1-9**). Because brown trout in the Grand Canyon spawn primarily in tributaries (e.g., Bright Angel Creek [RM 88] and Shinumo Creek [RM 109]), recruitment and abundance may be more affected by conditions in the tributaries than in the mainstem. Overall, catch rates in all reaches declined after about 2015.

Bright Angel Creek was identified as a potential site for translocation of humpback chub to start a second population in Grand Canyon (Valdez et al. 2000). Before translocations of fish could begin, the NPS determined the need to remove as many brown trout as possible from the creek. A trout control project, using a combination of a fish weir trap and electrofishing, was implemented by the NPS to benefit native species in Bright Angel Creek and humpback chub in the Colorado River. Control measures were implemented in winters 2006–2007, 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015 under the 2006 and 2013 EAs and a Finding of No Significant Impact (FONSI; NPS 2006, 2013d). Concurrent with intensive mechanical suppression of invasive salmonids, the predominant stream-wide composition of the fish community in Bright Angel Creek shifted from trout (65 percent) in 2012 to native fish (greater than or equal to 77 percent) in 2015 (Healy and Schelly et al. 2020). By the end of the study in 2018, totals of 43,665 brown trout and 7,824 rainbow trout were removed, and native fish represented 97 percent of the fish community. Population estimates for brown trout steadily declined between 2012 and 2018 from a high of 13,829 to a low of 1,315, resulting in a 91 percent reduction by the 2017–2018 sampling season (Healy and Schelly et al. 2020).

Brown trout in the Grand Canyon have shown an ability to move considerably in the Colorado River, sometimes from one tributary to another. Some brown trout captured in Bright Angel Creek were originally tagged in other parts of the Colorado River, as much as 25 miles from Bright Angel Creek (Reclamation 2011). Small numbers of brown trout are also found in other locations within the Grand Canyon, including in the vicinity of the Little Colorado River confluence, where they pose a threat to humpback chub (Valdez and Ryel 1995). A telemetry study documented brown trout moving both up and downstream from Lees Ferry. Detections included one adult brown trout moving from Lees Ferry to just downstream of the Little Colorado River confluence (Schelly et al. 2021). An indication of the relative abundance of brown and rainbow trout in the vicinity of the Little Colorado River is provided by the numbers captured using electrofishing during trout removal efforts (Coggins 2008). Of 23,000 nonnative fish captured as part of removal from 2003 to 2006, totals of 19,020 were rainbow trout and 470 were brown trout (Reclamation 2011). All brown trout removed during these efforts were in the mainstem.

Figure TA 8 Attachment 1-9
Mean Catch-Per-Unit-Effort (CPUE) of Brown Trout Captured during Electrofishing Surveys on the Colorado River between Lees Ferry and Pearce Ferry for Reaches 1–6 (plots A–F), 2000–2017



Data from AZGFD. Figure from Runge et al. (2018).

The brown trout population at Lees Ferry historically consisted of a small number of large fish supported by low levels of immigration from downstream reaches. Over the period 2014–2016, the number of brown trout captured during routine monitoring in the Lees Ferry reach began to increase (**Figure TA 8 Attachment 1-10**). Brown trout were observed spawning near the -4-mile bar in Glen Canyon during October and November of 2014 and 2015, and an increase in age-1 brown trout was observed in 2015 and 2016, likely the result of local spawning and recruitment (Korman et al. 2015). Management agencies and stakeholders questioned whether this increase in brown trout represents a threat to the rainbow trout sport fishery, as well as to downstream humpback chub aggregations. This population of brown trout showed signs of sustained successful reproduction and recruitment of locally hatched fish into the spawning class, based on analysis with a new integrated population model (Runge et al. 2018). The proximate causes of this change in status are a large pulse of immigration in the fall of 2014 and higher reproductive rates in 2015–2017, but the ultimate causes of this change are not fully clear.

Figure TA 8 Attachment 1-10
Index of Brown Trout Abundance (mean fish caught per minute of electrofishing) in Lees Ferry, 1991–2023

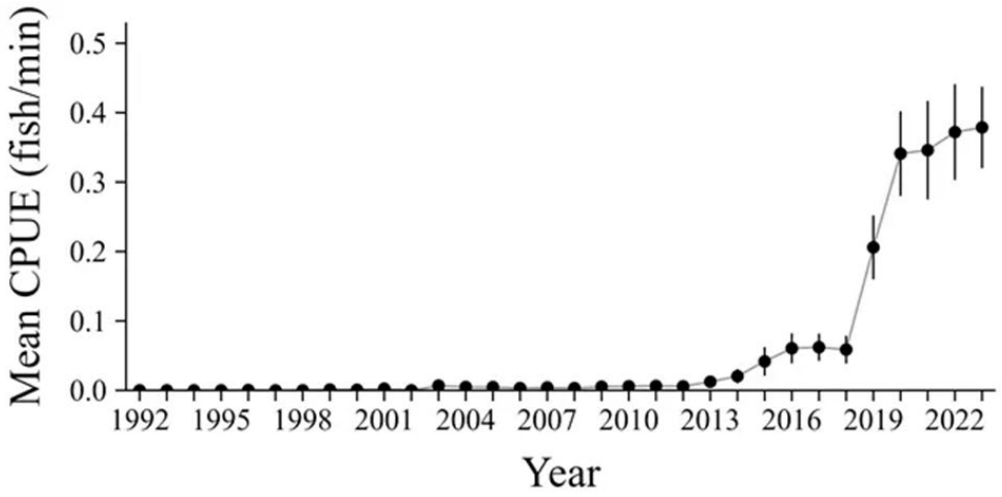


Figure from AZGFD (Rogowski 2023)
Note: The closed circles show the mean value; the whiskers show the 95-percent confidence intervals.

The pulse of brown trout immigrants from downstream reaches in fall 2014 may have been induced by three sequential high-flow releases from the dam in November of 2012–2014 but may also have been the result of a unique set of circumstances unrelated to dam operations. The increase in reproduction may have been the result of any number of changes, including an Allee effect, warmer water temperatures, a decrease in competition from rainbow trout, or fall high-flow releases. Correlations over space and time among predictor variables do not allow for a clear inference about the cause of the changes.

There are interventions that may be effective in moderating the growth of the brown trout population in the Lees Ferry reach (Runge et al. 2018). Across causal hypotheses, it is predicted that removal strategies (e.g., a concerted electrofishing effort or an incentivized take program targeted at

large brown trout) could reduce brown trout abundance by approximately 50 percent relative to status quo management. Reductions in the frequency or a change in the seasonal timing of high-flow releases from Glen Canyon Dam could be more effective, but only under the causal hypotheses that involve effects of such releases on immigration or reproduction. Brown trout management flows (i.e., dam releases designed to strand young fish at a vulnerable stage) may be able to reduce brown trout abundance to some degree, but are not forecast as the most effective strategy under any causal hypothesis.

A cost-effective strategy was identified that involves rewarding anglers monetarily for every brown trout removed from the river, as compared to intensive mechanical removal (i.e., electrofishing) (Runge et al. 2018). An incentivized harvest program was implemented in the Lees Ferry reach on November 11, 2020. For the next 5 to 6 years, eligible anglers would be offered a reward of at least $25 per brown trout over 6 inches in length removed from the Colorado River between Glen Canyon Dam and the mouth of the Paria River. This reward may vary with the seasons or be adjusted annually, but will typically be in the $25-$33 range. The usual reward is $33 per brown trout and $15 for each PIT tag.

Incentivized harvest has been ongoing for over three years (2020–2023) and has increased substantially in the last year. The adult brown trout population declined significantly in 2023, a significant portion of which can be attributed to incentivized harvest. From November 2020 through December 2023, anglers removed 5,597 brown trout and received $423,190 in payouts (NPS 2024).

The number of brown trout greater than 150 mm (5.9 inches) TL appeared to moderate after the incentivized harvest was implemented in late 2020, but the numbers increased to the highest level of over 11,000 fish in 2022 and declined to fewer than 6,500 fish in 2023 (**Figure TA 8 Attachment 1-11**). This indicates that the incentivized harvest of brown trout is working to reduce the numbers of fish, but the effects are confounded by several factors, including survival, recruitment, and environmental conditions.

Figure TA 8 Attachment 1-11
Estimated Numbers of Brown Trout larger than 150 mm (5.9 inches) TL in the Lees Ferry Sub-reach, 2000–2023

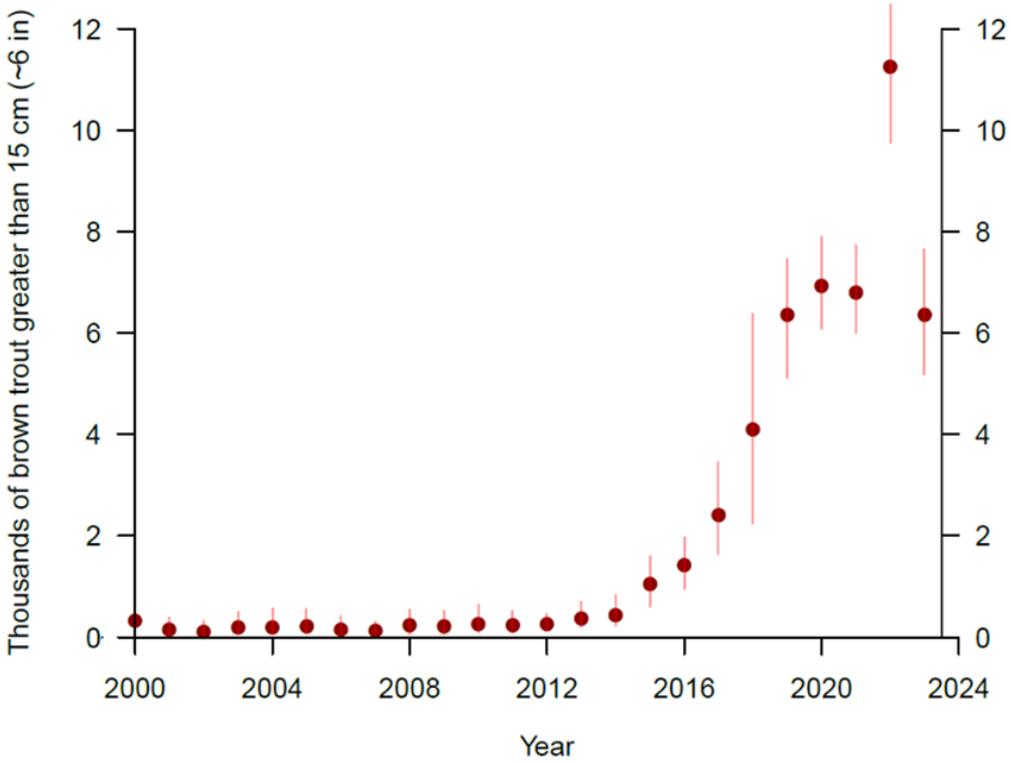


Figure from GCMRC Power Point (Yackulic et al. 2024)
Note: The closed circles show the mean value; the whiskers show the 95-percent confidence intervals.

Habitat

The brown trout is a cold-water fish species that inhabits streams, rivers, and lakes, and can migrate to and from salt water. Adults in streams typically use areas with overhead cover and deep pools, eddies, runs, and overhanging banks for resting, and they feed in open riffles. Juveniles use shallow habitats near cover, and recently hatched fry use shallow shorelines (Sigler and Sigler 1996). Brown trout prefer cover, and they can tolerate and feed at high temperatures and in higher turbidity than other salmonids, such as rainbow trout (Sigler and Sigler 1996). The upper limiting temperature for brown trout is 27.2 ºC (81 ºF; Sigler and Sigler 1996). Preferred temperatures for spawning, egg incubation, and growth are 7–14 ºC, 8–20 ºC, and 11–20 ºC (44.6–57.2 ºF, 46.4–68.0 ºF, and 51.8–68.0 ºF), respectively (Valdez and Speas 2007).

In Bright Angel Creek, brown trout use a variety of habitats that include pools, riffles, runs, and cascades. Brown trout from the mainstream Colorado River are attracted to tributaries like Bright Angel Creek by the availability of gravel riffles used as spawning habitat. Limiting access to those habitats by placing a weir at the mouth to intercept upstream adult spawners significantly reduced the numbers of brown trout in the stream, along with ongoing mechanical removal (Healy and Schelly et al. 2020).

Habitat use in the mainstream Colorado River through Grand Canyon is not well known. Adults appear to have relied on seasonally warmed tributaries, such as Bright Angel Creek, to spawn in an otherwise cold mainstem. With warmer releases from Glen Canyon Dam starting in 2004, brown trout increased in numbers by migrating to the Lees Ferry sub-reach and by apparent successful reproduction and recruitment (Runge et al. 2018). Brown trout appear to be using the same habitats for resting, feeding, spawning, egg incubation, and nurseries as rainbow trout in the Lees Ferry sub-reach, except that brown trout spawn in the fall (October-November) and rainbow trout spawn in early spring (February and early March).

Life History

The brown trout can reach a maximum size of nearly 40 pounds and typically matures between 2 and 3 years of age, with females producing 200–6,000 eggs in streams (Sigler and Sigler 1996). Females prepare individual nests or redds in gravel riffles or runs where they deposit eggs that are fertilized by multiple males. Brown trout initiate spawning in the fall with the onset of decreasing water temperatures in the range of 7.2–10 ºC (45–50 ºF), usually from late October to December. The eggs hatch in 41 days at a constant water temperature of 10 ºC (50 ºF; Sigler and Sigler 1996).

The brown trout has a largely carnivorous diet with younger fish feeding on aquatic and terrestrial insects, as well as mollusks, frogs, and rodents, and older fish feeding primarily on fish and large crustaceans like crayfish (Sigler and Sigler 1996). This propensity for piscivory is why NPS identified brown trout as a "(1) Very High" threat level to rainbow trout and native fish in Glen Canyon NRA and Grand Canyon National Park (NPS 2021). As subadults and adults, brown trout are 17 times more likely to eat other fish than rainbow trout, meaning that even small numbers of brown trout can impose a significant predator threat to native fish (Yard et al. 2011).

Smallmouth Bass

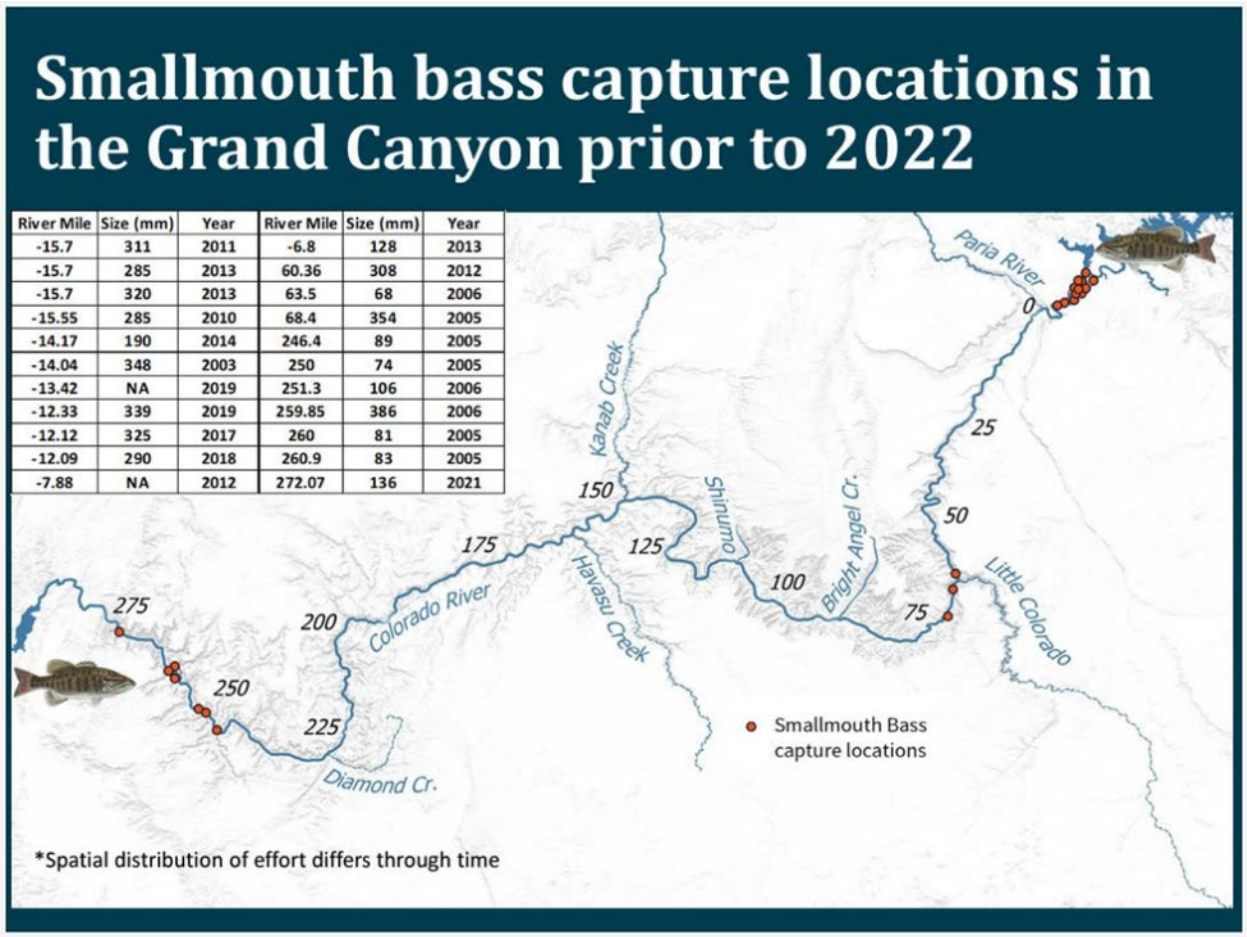
The smallmouth bass is considered the most problematic nonnative fish species in the Upper Basin in terms of negative impacts on native fish populations and endangered fish recovery (Bestgen et al. 2008, 2018; Breton et al. 2015). Based on results of a bioenergetics model, Johnson et al. (2008) ranked smallmouth bass as the most problematic invasive species in the Upper Basin because of their high abundance, habitat use that overlaps with most native fish, and ability to consume a wide variety of life stages of native fish. Expanded populations of piscivores such as smallmouth bass are a major impediment to conservation actions aimed at recovery of the four endangered fish in the Upper Basin (FWS 2018a, 2020). Smallmouth bass also pose a threat to desirable sportfish, such as rainbow trout. The smallmouth bass was introduced into Lake Powell in 1982 and has periodically been detected downstream of Glen Canyon Dam, where it poses a threat to native, endangered, and threatened species, such as humpback chub (Smallmouth Bass Management Review Committee 2024).

Distribution and Abundance

The smallmouth bass is native to eastern North America west of the Appalachian Mountains, but it has been widely introduced throughout the U.S. as a sportfish and for nuisance fish control. The smallmouth bass was introduced into reservoirs of the Upper Basin starting in 1967 (Pettengill et al. 1983). It was stocked into Lake Powell in 1982 and has been detected sporadically in the Colorado River downstream of Glen Canyon Dam since early 2000. Prior to 2022, there were records of 22

individuals being caught between Glen Canyon Dam and Pearce Ferry (**Figure TA 8 Attachment 1-12**). Capture locations show three concentrations of fish, including at the Lees Ferry reach downstream of the dam, near the confluence of the Little Colorado River, and in the newly exposed channel at the inflow to Lake Mead. The likely origin of these fish is passage through the dam, moving down the Little Colorado River from upstream reservoirs, and moving upstream from Lake Mead, respectively. Greater numbers of smallmouth bass have been captured in the Lees Ferry reach in 2022 and 2023, which have either passed from Lake Powell through the dam penstocks or have been recently spawned in the area. Most of the smallmouth bass in the Lees Ferry reach have been caught in and near the -12-mile slough (located 12 miles upstream of Lees Ferry), a small side channel of the Colorado River that can entrain and warm water released from the dam (GCMRC 2014). Prior to 2022, the bass were mostly large subadults and adults, suggesting that these fish survived passing through the penstocks from Lake Powell. Starting in 2022, many of the bass were smaller, indicating that these fish were produced locally, probably in and around the -12-mile slough.

Figure TA 8 Attachment 1-12
Smallmouth Bass Capture Locations in the Grand Canyon Prior to 2022



Source: GCMRC 2014

Within the analysis area, smallmouth bass are found along rocky shorelines in Lake Powell as a sportfish, in the Lees Ferry reach, near the Little Colorado River, and in the western Grand Canyon; they are also a popular sportfish along rocky shorelines in Lakes Mead, Mohave, and Havasu, and suitable riverine and lake habitats to the SIB.

Habitat

The smallmouth bass inhabits large rivers, streams, lakes, and ponds. Within its native range, it is most abundant in pools of streams that consist of a substantial proportion of riffle habitat, clean, rocky, hard bottoms, and gradients of 0.5-5.0 m/km (2.6-26 feet/mile). In large rivers and lakes, smallmouth bass tend to congregate over hard, rocky bottoms, where currents are present. Currently, smallmouth bass occur in the mainstream Colorado River, in the Verde River, and throughout the Salt River below about 2,200 m (7,218 feet) elevation (Reclamation 2018).

In late summer and autumn during low flows, adults use habitats that consist mostly of low-velocity runs or pools separated by shallow, higher-velocity riffles. Substrate is typically a mix of boulder, cobble, gravel, and sand in low-velocity areas, and cobble and gravel in riffles. Young life stages use shallow riffles with cobble and gravel substrates. Spawning takes place in backwaters and isolated pools that are created by cutoff high-flow side channels and contain cobble, gravel, and fine-grained substrate (Bestgen and Hill 2016b).

Life History

The smallmouth bass is a large member of the sunfish family (Centrarchidae) that can reach sizes of about 69 cm (27 inches) and 5.4 kg (12 pounds). Smallmouth bass spawn in spring, usually mid-April to July, depending on geographical location and water temperature. The species is highly sensitive to flow and water temperature, which greatly influence reproductive success (Winemiller and Taylor 1982; Peterson and Kwak 1999). Large fluctuations in water level can affect the reproductive success of smallmouth bass (Pflieger 1997; Montgomery et al. 1980). Ideal spawning conditions include one or more substantial rises in water level a week or two prior to nesting (Pflieger 1997) and relatively stable water levels while nesting is in progress (Watson 1955; Pflieger 1997). Rising water can flush nest areas with cold water, causing nest desertion and halting embryo development (Watt 1959; Montgomery et al. 1980). Falling water levels can drive guarding males off, limit water circulation around eggs, and increase predation, resulting in lower reproductive success (Neves 1975; Montgomery et al. 1980).

Spawning is initiated when male smallmouth bass construct nests in low-velocity stream habitat, usually channel margin backwaters or cutoff secondary channels, by fanning fine sediment to reveal the gravel and cobble substrate. Nests are built in low-velocity areas because eggs and weak-swimming larvae will otherwise be swept away by even relatively slow water currents 5–22 cm/second (2–9 inches/second; Larimore and Duever 1968). Females are attracted to nests by males, and eggs are deposited and fertilized over the surface of the substrate. Fertilized eggs are semi-adhesive and develop on the surface of the substrate as the male guards them from predators. After hatching, larvae lie on the bottom for several days, and after 1–2 weeks rise from the substrate and gain buoyancy, while still being guarded by the male. Those vulnerable eggs and weak-swimming fry are the life stages most susceptible to changes in flow rates that may sweep eggs and fry away and reduce their survival (Bestgen and Hill 2016b).

Mature females produce 2,000–15,000 golden yellow eggs. Males may spawn with several females on a single nest. On average, each nest contains about 2,500 eggs, but nests may contain as many as 10,000 eggs. Eggs hatch in about 10 days if water temperatures are in the mid-50s (°F), but can hatch in 2–3 days if temperatures are in the mid-70s (°F). Males guard the nest from the time eggs are laid until fry begin to disperse, a period of up to a month.

Temperature is one of the most important factors limiting the distribution of smallmouth bass (Bestgen 2018). Faster growth rates of adults are generally associated with higher summer temperatures. Faster growth rates occur in southern reservoirs, resulting in a shorter life span than in northern regions. In summer, smallmouth bass inhabit warmer shoreline areas of large lakes in the north and deeper, cooler waters in the south. Growth does not begin until water temperatures reach 10–14 °C (50–57 °F). Field data indicate that adults prefer temperatures of about 21–27 °C (70–81 °F) in summer. Smallmouth bass have been reported "sunning" themselves in pools with water temperatures of about 26.7 °C (80 °F) in summer (Edwards et al. 1983). When temperatures drop to 15–20 °C (59–68 °F), adults seek deep, dark areas. At about 10 °C (50 °F), bass become inactive and seek shelter. At 6–7 °C (42.8–44.6 °F), most smallmouth bass are beneath the rock substrate, with few remaining on top. The lower lethal temperature is near freezing. Bass will congregate around warm springs in winter when available.

Fry seem to be especially vulnerable to flood conditions and fluctuating water levels (Larimore 1975). A rapid drop in water level may trap them in areas where they will become desiccated (Montgomery et al. 1980). A stream rise of only a few inches, and consequent increase in water velocity, can displace advanced fry newly risen from the nest (Webster 1954). Most fry remain in shallow water (Doan 1940; Forney 1972), although some can be found at depths of 4.6–6.1 m (15–20 feet) (Stone et al. 1954; Forney 1972). Fry 20–25 mm (0.79–1 inch) in length cannot maintain themselves in current velocities faster than 200 mm/second (7.9 inches/second;Larimore and Duever 1968). An increase in turbulence during flood conditions creates conditions with which smallmouth fry appear unable to cope (Webster 1954). Fry cannot tolerate and are displaced at high turbidities (2,000 Jackson Turbidity Units) combined with an increase in water velocity, but they will not be displaced at moderate turbidities (250 Jackson Turbidity Units) (Larimore 1975). Low water temperatures during flood conditions will reduce fry swimming ability (Larimore and Duever 1968).

Bestgen and Hill (2016b) studied patterns of smallmouth bass reproduction in partially regulated and unregulated reaches of the Green River and the unregulated Yampa River of the Upper Colorado River Basin. Patterns of reproduction in the Yampa River contrasted with regulated or partially regulated Green River reaches, where smallmouth bass reproduction occurred later, and sometimes well after water temperatures reached the threshold 16 °C (60.8 °F). In the regulated reach of the Green River, successful hatching did not occur until relatively low and stable baseflow levels were reached, noting that high streamflow in 2011 delayed hatching. They postulated that stable baseflows were required for smallmouth bass so that spawning habitat was available and suitable for successful reproduction; spawning at higher flows may have been attempted, but could not be determined.

The existence of established smallmouth bass populations in Lake Powell, combined with the passing of epilimnetic water from the lake through Glen Canyon Dam to the Colorado River downstream, creates a conduit for repeated introductions of smallmouth bass downstream of Glen

Canyon Dam. This complicates efforts to minimize the risk of smallmouth bass establishment and expansion in the river downstream of the dam. While directed removal efforts can take place in areas where smallmouth bass have been identified, introductions of smallmouth bass from Lake Powell could continue unless deterrents are developed. A selected option for releases from Glen Canyon Dam is currently being implemented and evaluated as directed by the Secretary of the Interior's designee (LTEMP SEIS, Reclamation 2024). The cool mix option was selected as the most likely to minimize spawning by smallmouth bass. This option involves releasing water from Glen Canyon Dam as a mixture of cold water from the deeper river outlet works (bypass valves or jet tubes) with warmer water through the penstocks that create cooler water conditions to prevent smallmouth bass from reproducing and establishing downstream of Glen Canyon Dam. This release takes place when a mainstream water temperature of 16 °C (60.8 °F) is reached near the confluence of the Little Colorado River (RM 61), the temperature at which smallmouth bass spawning behavior begins for introduced populations in the Upper Colorado River Basin (Bestgen and Hill 2016b). The cool mix releases were conducted under the authority of the 2024 LTEMP SEIS and reflect approved experimental treatments under LTEMP for the Grand Canyon and not as part of this Final EIS.

Green Sunfish

The green sunfish is a medium-sized member of the sunfish family (Centrarchidae) with a maximum length of about 275 mm (10.8 inches) TL and 960 grams (2.1 pounds; Sigler and Sigler 1996). Although not native to the Colorado River, it was common in Glen Canyon before dam construction in 1958-59 (McDonald and Dotson 1960) and shortly after dam construction in 1967-1968 (Stone and Rathbun 1968). It became rare in the mainstream Colorado River after cold dam releases began in the 1970s, except at the mouths of seasonally warmed tributaries like the Little Colorado River and Kanab Creek (Valdez and Ryel 1995). The numbers began to increase in the mainstem with warmer dam releases starting in 2004, and in 2015–2017, green sunfish were found spawning and successfully reproducing in the -12.5-mile slough (Ward 2015; NPS 2018). Evidence of reproduction was found in Kanab Creek (Healy and Ward et al. 2020) and at RM 243 (Smallmouth Bass Management Review Committee 2024). The green sunfish is a small but effective predator of small fish, and a reproducing population in the Grand Canyon poses a risk to native fish populations. The green sunfish is one of six nonnative fish species designated by the NPS as a "(2) High" threat level for native fish in Glen Canyon NRA and Grand Canyon National Park (NPS 2021).

Distribution and Abundance

The green sunfish is native to east-central North America, from southwestern New York, west of the Appalachian Mountains, south to Georgia, Alabama, west and south to Texas, northeastern Mexico, and New Mexico (Sigler and Sigler 1996). It was first introduced into the Colorado River system with various other sportfish after Lake Mead began forming in 1935. It was also introduced by state game and fish agencies as a mixture of sportfish throughout lakes and streams of the system, and is considered a sportfish in Lakes Powell, Mead, Mohave, and other waters of the Lower Basin. It is abundant in tributaries of the Grand Canyon, including the Little Colorado River (Stone et al. 2018). As summarized by Valdez and Ryel (1995), small numbers of green sunfish were found in the Grand Canyon in 1970–73, 1975, 1977–78, 1984–86, and 1990–93. Only one adult green sunfish was captured during the 2000 Low Steady Summer Flow experiment (Trammell et al. 2002),

and no green sunfish were reported in the 2016 System Wide Monitoring Project from Lees Ferry to Lake Mead (Rogowski et al. 2017).

The lower levels of Lake Powell starting in about 2000 have enabled some lake fish to become entrained in the dam penstocks and enter the Colorado River downstream. Lower lake levels have also resulted in warmer dam releases that have enabled warmwater fish like green sunfish and smallmouth bass to spawn downstream of the dam. Although green sunfish have been present in the river since dam construction, their numbers have remained low, and they have not been considered a threat to native fish (Valdez and Ryel 1995). However, numbers began to increase because of dam entrainment and local reproduction, and the NPS decided to act. In November 2015, the NPS found evidence of reproduction by green sunfish in a slough located 3 miles downstream of Glen Canyon Dam (-12-mile slough, 12 miles upstream from Lees Ferry), and the slough was treated with rotenone (a chemical piscicide) to eradicate green sunfish. Additional green sunfish were discovered in the slough in 2016 that were believed to be passing through the dam penstocks from Lake Powell, and in 2018, the Bureau of Reclamation requested temperature reduction options to cool the water in the slough so that green sunfish and other invasive species (e.g., smallmouth bass) could not spawn. A series of temperature reduction options were developed (Greimann and Sixto 2018), but have not been fully implemented. A second rotenone treatment was applied to the -12-mile slough in August 2023.

Numbers and lengths of green sunfish captured in the Lees Ferry reach have been recorded and analyzed as part of the Trout Recruitment and Growth Dynamics project in Glen Canyon between June 2022 and November 2023 (Smallmouth Bass Management Review Committee 2024). These data were used to estimate the capture probability of green sunfish and smallmouth bass. The number of green sunfish is greater and provides more reliable statistics for two sub-reaches, reach 1A (RM -14.3 to -12.5 mile with its downstream end located just upstream of the slough) and 1C (-4.3 to -2.7 mile). The average green sunfish abundance was ~3,900 and 390 in reaches 1A and 1C, respectively. Green sunfish abundance was ~10-fold higher in the reach closer to the dam (1A), located upstream of the slough. The average abundance of smallmouth bass was 182 and 28 in 1A and 1C, respectively. Smallmouth bass abundance in 1A was ~ 6-fold higher than in 1C. Green sunfish abundance was 21-fold higher than smallmouth bass abundance in 1A, and 14-fold higher in 1C. Higher numbers of green sunfish from the sub-reach closer to the dam indicates that the fish were passing through the dam from Lake Powell, but the presence of small fish is evidence of local reproduction (**Figure TA 8 Attachment 1-11**).

Within the analysis area, green sunfish (and other sunfishes) are found along shorelines in Lake Powell, in the Lees Ferry sub-reach, near the Little Colorado River, and in the western Grand Canyon. They are also a popular sportfish along shorelines in Lake Mead, Lake Mohave, and Lake Havasu, and most likely wherever there is suitable riverine and lake habitat downstream to the SIB.

Habitat

Green sunfish inhabit small, warm streams, ponds, and shallow areas of lakes. They occur over a variety of habitats and in a variety of covers, including emergent vegetation, woody debris, and rocks. Green sunfish can tolerate a range of water temperatures from cool (18–21 ºC; 64.4–69.8 °F) to warm (30–32 ºC; 86–89.6 °F) conditions.

Green sunfish spawn in spring in water 0.61–2.44 m (2-8 feet) deep at temperatures of 18.9 ºC (66.0 ºF). They can spawn multiple times until the temperature reaches about 28 ºC (82.4 ºF). Males construct oval nests near rocks, logs, clumps of grass, or other debris, and escort individual females to deposit eggs over the nest. Females produce 2,000–26,000 eggs, and the eggs incubate 3–5 days at 23 ºC (73.4 ºF). More than one female may deposit eggs on the nest, and the male defends the nest aggressively (Sigler and Sigler 1996).

Life History

Green sunfish live up to about 10 years of age and can reach sizes of 275 mm (10.8 inches) TL and 300 grams (0.7 pounds). They have high reproductive survival and are highly predaceous starting with the earliest life stages. They feed on small fish and can dominate small ponds when introduced into a bluegill (*Lepomis macrochirus*)/largemouth bass (*Micropterus salmoides*) fishery. They also consume aquatic and terrestrial insects, crustaceans, and amphibians, and they can hybridize with other species of sunfishes of the genus *Lepomis* (Sigler and Sigler 1996). These aspects of the life history of the green sunfish make it a high threat to local native fish populations.

Flathead Catfish

The flathead catfish is a large North American freshwater catfish species. Adult flathead catfish can reach lengths of between 90 and 120 cm (35 to 47 inches), with some individuals growing even larger. The species have been captured weighing 23 kg to 45 kg (51 to 99 pounds; TPWD 2024). Flathead catfish are gray to brown with dark brown-black mottling that may extend ventrally onto the belly. The undersides of the head and body are white to yellow. Their nasal and maxillary barbels are dark, and their chin barbels are white to yellow. The head is broadly flattened, with a projecting lower jaw. The tail fin is only slightly notched, not deeply forked (Pflieger 1997; Ross 2001; Fuselier 2014; TPWD 2024).

Distribution and Abundance

The flathead catfish is native to the U.S., with its original distribution covering the Mississippi River Basin and Great Lakes region (TPWD 2024). They are widely distributed in the Mississippi River Valley, ranging from South Dakota and Pennsylvania south to the Gulf Coastal Plain. It also occurs in large rivers of the Gulf of America Basin, from the Mobile Basin west to the Rio Grande (Minckley and Deacon 1959; Hubbs et al. 2008; Glodek 1980). Over time, flathead catfish have been introduced to many other water systems across the country, sometimes leading to ecological challenges due to their predatory nature and competition with native species, including in the Lower Colorado River Basin. Due to its desirability as a sportfish, it has been widely stocked outside of its native range (Young and Marsh 1990).

Due to its large size and palatable flesh, flathead catfish have been introduced into parts of Arizona, California, Florida, Idaho, New Mexico, Oregon, and South Carolina (Moyle 1976). The first introduction in the Southwest was to the Gila River system in New Mexico or Arizona sometime prior to 1950 (Young and Marsh 1990). In 1962, the AZGFD stocked flathead catfish at six locations along the Lower Colorado River (Bottroff et al. 1969). Subsequent introductions from 1968 to 1975 occurred in the Salt, Verde, and San Francisco Rivers of Arizona. Since these initial introductions, flathead catfish have spread to inhabit waters throughout the lower Colorado, Gila, Salt, and Verde Rivers in Arizona. Population size varied with discharge in the lowermost Colorado

River and was estimated to range from 155 to 259 flathead catfish per km when discharge was at its maximum in 1986 (Young and Marsh 1990).

Habitat

Flathead catfish prefer habitats in large rivers and streams, as well as reservoirs and lakes with slow-moving or still waters; they favor areas with deep pools, undercut banks, and abundant cover, such as submerged logs, rocks, and debris (Fuselier 2014; Pflieger 1997; TPWD 2024). They occupy a variety of stream types while avoiding high gradients or intermittent flow. It is not likely to be found in headwater creeks (Pflieger 1997). These environments offer both protection and an ample food supply, primarily consisting of live prey such as other fish, as well as crustaceans. Flathead catfish are known to be nocturnal predators, often hunting during the night and relying on their keen sense of smell and taste to locate prey in the dark, turbid waters they inhabit (Ross 2001; Fuselier 2014; TPWD 2024). Optimal water temperatures for flathead catfish range from 25 to 30ºC, but they can tolerate a broader range (TPWD 2024).

Life History

Flathead catfish have a relatively slow growth rate compared to other freshwater fish, with individuals taking several years to reach maturity. They can live for 12 years or more, with some documented cases of individuals living over 20 years (Fuselier 2014; Pflieger 1997; TPWD 2024). Spawning typically occurs in late spring to early summer when water temperatures reach approximately 20 to 26 °C (Fuselier 2014; Pflieger 1997; TPWD 2024). During this time, male flathead catfish prepare nests in secluded, sheltered areas, such as hollow logs, cavities under rocks, or human-made structures like submerged pipes or riprap. Once the nest is prepared, the male attracts a female to the site, where she can lay up to 100,000 eggs, depending on the size of the female. After fertilization, the male takes on the role of guarding the nest from predators (Ross 2001; TPWD 2024).

Flathead catfish are of particular concern as they are voracious predators and pose a substantial threat to native fishes. This species appears to be expanding its range from Reaches 4/5 and upstream within Reach 3 (potentially due to temperature), and as such, it is routinely monitored by FWS personnel. This species had been captured nearly as far upstream as the area between Needles and Fort Mohave in the Lower Colorado River (near Boundary Cone Road crossing) (Rasset and Love-Chezem 2024).

The rapid dispersal and population growth rates of introduced flathead catfish, coupled with their obligate carnivorous feeding habits, have raised concerns among ichthyologists and management agencies. The FWS has ranked flathead catfish as its highest priority among invasive animal species in the southeastern U.S. (Brown et al. 2005).

Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
AZGFD	Arizona Game and Fish Department
BLM	Bureau of Land Management
CI	confidence interval
cm	centimeter
CPUE	catch per unit effort
EIS	environmental impact statement
ESA	Endangered Species Act
FWS	United States Fish and Wildlife Service
HFE	high-flow experiment
IUCN	International Union for Conservation of Nature
kg	kilograms
km	kilometers
Lower Basin	Lower Colorado River Basin
m	meters
Mexico	United Mexican States
mm	millimeters
NPS	National Park Service
NRA	National Recreation Area
PIT	passive integrated transponder
RM	river mile
SIB	Southerly International Boundary
TL	total length
U.S.	United States
YOY	young-of-year

Glossary

Analysis Area	Specific geographic boundary and timeframe used to evaluate the potential environmental effects of a proposed action
auspices	Sponsorship, guidance, or protection provided by an organization or authority
backwaters	Areas of slow-moving or stagnant water connected to a river or stream
bioenergetics model	A mathematical model that quantifies the balance between energy intake from food consumption and energy release through metabolism, activity, waste, and reproduction
broadcast	A reproductive method in which eggs and sperm are released freely into the water column for external fertilization
cascades	Steep, high-energy sections of a stream or river characterized by boulder-dominated beds and turbulent flow

critical habitat	Areas officially designated under the Endangered Species Act as essential for the recovery and survival of endangered or threatened species
congeneric	Belonging to the same genus
creel census	Data collected from anglers to estimate catch, harvest, and success rates
debris flow	A fast-moving mass of water-saturated soil, rock, and organic material that travels downslope under the influence of gravity
eddy	Localized area of recirculating flow
deltaic	Anything related to, formed by, or characteristic of a river delta
downlisting	Changing a species' legal status under the Endangered Species Act from "endangered" to "threatened"
endemic	Refers to a species that is native to and restricted within a defined geographic area
extirpated	Describes a species that no longer exists in a localized zone
fecundity	The reproductive capacity of an organism
fidelity	The tendency of an organism to return to or remain in a specific location or habitat type
fry	The early free-swimming life stage of fish that begins after the yolk sac is absorbed and the individual starts active feeding
hydropower operations	The management of reservoir storage and water releases through turbines and spillways at hydroelectric facilities to produce electricity
impoundment	A human-made basin or reservoir created by a dam, berm, or other structure that holds or stores water
inundated	Covered or submerged by water, either seasonally or permanently
Interagency Standardized Monitoring Program (ISMP)	A general description for cooperative monitoring efforts between government agencies, rather than a single program
larval drift	The downstream transport of newly hatched fish by river currents
Lower Colorado River Multi-Species Conservation Program (LCR MSCP)	A comprehensive program for the protection of 27 species and their habitat in the Lower Colorado River Basin
mainstem	The principal or primary channel of a river system
mark-recapture	A population estimation method in which individual organisms are captured, marked, and released, then later recaptured to determine population loss

meristically	Anatomical traits used in describing or identifying species
nursery habitat	Habitat that provides favorable conditions for the survival and growth of juvenile life stages
oxbow pond	A U-shaped or crescent-shaped waterbody formed when a river meander becomes cut off from the main channel
penstock	A pipe that moves water under pressure from a reservoir or intake structure to turbines in a hydroelectric system
piscivory	The feeding behavior of eating fish
PIT-tagged	Describes an organism that has been implanted with a small microchip that contains a detectable code by a specialized scanner
progeny	Offspring or descendants produced by an organism
radio tagged	Describes an organism that has been equipped with a radio transmitter that emits detectable electromagnetic signals
radiotelemetry	A tracking method that uses radio transmitters and receivers to locate and monitor the movement and behavior of organisms
recruitment	The addition of new individuals to a population or to a specific life stage
recurrent channels	Secondary or alternative flow paths within a river or floodplain that periodically carry water during certain flow conditions
redd	A nest created by a female fish where she deposits and buries her eggs in gravel
refugia	Areas that provide shelter or protection for species or communities during periods of environmental stress
ripe fish	A sexually mature fish whose reproductive organs are fully developed and capable of releasing eggs or sperm
rotenone	Naturally derived fish toxin used to eliminate unwanted or invasive fish species from waterbodies
silt-laden	Containing or heavily mixed with fine particles
slack water	Water with little to no current velocity often occurring along channel margins or in backwater areas
slough	A slow-flowing or stagnant side channel, backwater, or wetland area associated with a river, floodplain, or estuary
sonic tagged	Describes an organism equipped with an acoustic transmitter that emits sound pulses detectable by monitories
stocking	Intentional release of fish into a waterbody to supplement natural populations
stratified releases	Controlled discharge of water from specific depths within a reservoir to manage temperature, oxygen levels, or water quality

stressor	Any chemical, physical, or biological factor that can cause adverse effects on an organism, population, or ecosystem
talus	Sloping accumulation of loose rock fragments that collects at the base of a cliff or steep slope due to mass wasting processes
telemetry	The remote detection and transmission of data from tagged organisms or monitoring devices to receivers for analysis
total dissolved solids	A measure of all inorganic and organic substances dissolved in a volume of water, including minerals, salts, and organic matter
translocation	Intentional movement and release of organisms from one location to another

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Technical Appendix 9

Vegetation Including Special Status Species

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Attachments

TA 9 Attachment 1. Special Status Plant Species
TA 9 Attachment 2. Parker and Davis Dams DMDU Figures

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2024 LTEMP SEIS	Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement
CCS	Continued Current Strategies
cfs	cubic feet per second
DMDU	Decision Making under Deep Uncertainty
FWS	United States Fish and Wildlife Service
HCP	Habitat Conservation Plan
HFE	high-flow experiment
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
maf	million acre-feet
RM	river mile
SIB	Southerly International Boundary
U.S.	United States
WY	water year

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TA 9. Vegetation Including Special Status Species

TA 9.1 Affected Environment

This analysis categorizes vegetation into marsh, woody riparian, and upland habitat types (collectively referred to as terrestrial habitats) throughout the analysis area, which includes Lake Powell, Glen Canyon Dam to Lake Mead, Lake Mead, and Hoover Dam to the Southerly International Boundary (SIB; see **TA 9.2**). Wetlands in the analysis area are typically characterized by marsh habitat, but wetlands could also occur in woody riparian habitats.

Marsh habitats occur in areas that are consistently flooded and are typically found in the transition zone between open water and upland ecosystems. Dominant vegetation in marsh habitat includes graminoids, such as cattails (*Typha* spp.), bulrush (*Schoenoplectus* spp.), and common reed (*Phragmites australis*). Marsh vegetation is sensitive to drought on short timescales, seasonally to annually, and has been found to decrease in cover, species diversity, and productivity when water availability shifts from perennial to intermittent (Stromberg et al. 2005, 2007; Friedman et al. 2022).

Woody riparian habitats occur where water is consistently available and periodic flooding occurs. Dominant vegetation types in woody riparian habitat include woody shrubs and trees, such as cottonwood (*Populus* spp.), mesquite (*Prosopis* spp.), tamarisk (*Tamarix* spp.), arrowweed (*Pluchea* spp.), seep willows (*Baccharis* spp.), and willow (*Salix* spp.). Woody riparian vegetation typically has deeper root systems capable of accessing alluvial groundwater and does not depend on surface water flows (Stromberg et al. 2013). This vegetation type is sensitive to drought on longer timescales, on an annual to decadal scale, depending on the species (Shafroth et al. 2002).

Upland habitats occur in areas without consistent water availability, where vegetation depends on precipitation. Dominant vegetation in the upland habitat is typically desert scrub dominated by various shrub species, such as creosote bush (*Larrea tridentata*) and bursage (*Ambrosia* spp.).

This section also includes special status plant species, defined here as those listed as Bureau of Land Management sensitive species by the overlapping Arizona, California, Utah, and Nevada Bureau of Land Management field offices; species covered in the Lower Colorado River Multi-Species Conservation Program (LCR MSCP); and species listed as threatened or endangered or proposed for listing by the United States (U.S.) Fish and Wildlife Service (FWS; BLM 2017, 2018, 2019, 2023; LCR MSCP 2022; FWS 2025). **TA 9 Attachment 1**, Special Status Plant Species Table, provides a list of the species considered in this document, including their listing status, the river reaches they typically inhabit, and the habitat types they occupy. **TA 9 Attachment 1**, Special Status Plant Species Table, was developed through input from cooperating agencies and local experts.

Culturally important plants are discussed in **TA 13**, Tribal Resources.

TA 9.1.1 Lake Powell

Short-term and long-term fluctuating water elevations influence Lake Powell's shoreline vegetation (**Table TA 9-1**). The median annual water elevation fluctuation between 2008 and 2025, when the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), were in effect, was 31.45 feet (see **Figure TA 9-1**). The drought-induced drawdown of Lake Powell since 2011 has reduced the lake's perimeter and exposed approximately 59,000 acres of formerly submerged land (Root and Jones 2022).

Table TA 9-1
Approximate Acres of Marsh, Woody Riparian, and Upland Habitat in Each Reach

Reach	Marsh (% of reach)	Woody Riparian (% of reach)	Upland (% of reach)	Total
Lake Powell[1]	1 (<1%)	10,802 (41%)	15,385 (59%)	26,188
Glen Canyon Dam to Lake Mead[2]	96 (3%)	353 (11%)	2,627 (85%)	3,076
Lake Mead[3]	388 (<1%)	6,657 (9%)	64,186 (90%)	71,250
Hoover Dam to the SIB[3]				
Hoover Dam to Davis Dam	36 (5%)	164 (22%)	558 (73%)	758
Davis Dam to Parker Dam	1,069 (20%)	1,990 (38%)	2,195 (42%)	5,254
Parker Dam to Cibola Gage	1,196 (5%)	20,604 (83%)	2,949 (12%)	24,749
Cibola Gage to Imperial Dam	738 (5%)	10,639 (77%)	2,411 (17%)	13,788
Imperial Dam to the Northerly International Boundary	439 (5%)	6,844 (76%)	1,654 (19%)	8,973
Northerly International Boundary to the SIB	10 (<1%)	152 (9%)	1,473 (90%)	1,635
Total	**3,973**	**58,205**	**93,438**	**155,671**

Sources: [1] NPS 2014; [2] Durning et al. 2018; [3] Sound Science 2025
Note: Totals may not equal 100 percent due to rounding.

Historically, marsh and woody riparian vegetation around Lake Powell are restricted due to the natural rocky, desert terrain that extends directly to the water's edge (NPS 2023; Reclamation 2016, 2024). As shown in **Table TA 9-1**, the majority of the reservoir shoreline is upland habitat. Of the 15,385 acres of upland habitat, 7,119 acres were mapped as bare sandstone or slickrock, and 1,044 acres were mapped as sand bar, sand islands, badlands, and other bare dirt areas (NPS 2014). Russian thistle (*Salsola* spp.) is the dominant upland species found along the shores of Lake Powell. Of the 15,385 acres of upland habitat described in **Table TA 9-1**, 1,048 acres were mapped as weedy herbaceous complex, of which Russian thistle is the dominant species (NPS 2014; Tendick et al. 2017). Russian thistle easily takes root on disturbed or bare ground, often establishing before native species (NPS 2023). Recently exposed sites below Lake Powell's full pool showed a higher percentage and cover of nonnative species, with Russian thistle being extremely abundant (Arens 2023).

Long- and short-term fluctuations in reservoir elevations have also had a significant impact on the establishment of marsh and woody riparian vegetation (Reclamation 2016, 2024). Marsh vegetation is extremely limited along Lake Powell, and the 1 acre of marsh vegetation described in **Table TA 9-1** is mapped as spring-supported herbaceous vegetation. Tamarisk is the dominant woody riparian species along the shores of Lake Powell. Of the 10,802 acres of woody riparian habitat described in **Table TA 9-1**, 10,773 acres were mapped as tamarisk shrublands (NPS 2014). Dense stands of tamarisk can displace native plants, degrade wildlife habitat, reduce livestock forage, limit human access, interfere with the natural fluvial processes, alter the ecology and hydrology of riparian systems, and increase the risk of severe wildfires (NPS 2023). Many tamarisk stands were likely established during higher lake elevations and are now showing severe drought stress or mortality as reservoir levels remain low (Arens 2023). The remaining 29 acres of mapped woody riparian habitat were native species vegetation classes, which included coyote willow shrublands, relict spring-supported mixed-deciduous woodlands and shrublands, and Fremont cottonwood (*Populus fremontii*) woodland (NPS 2014). These classes are associated with the major rivers (Colorado, Escalante, and San Juan) and the tributary side canyons (Tendick et al. 2017).

Long-term decreases in water elevations have resulted in standing water and backwater pools in some of the over 90 tributary side canyons of Lake Powell (NPS 2026). Plant surveys were conducted at 20 locations within tributary side canyons along the Escalante River and in exposed areas of Lake Powell bays in 2022 and 2023. At these locations, native shrubs were outcompeting nonnative plants on sites that had been exposed for more than three years, providing diverse ecosystems where natural flow patterns are re-established, including hanging gardens and cryptobiotic crusts (Arens 2023). In these tributary side canyons and along some portions of the major rivers, native woody riparian and marsh vegetation have begun to re-establish. Dominant plants found in areas of canyons include Fremont cottonwood, tamarisk, and cattail (Arens 2023).

In two study areas in the backwaters of Lake Powell, one along the San Juan River and one on the mainstem of the Colorado River, lake water elevations decreased approximately 28 meters between 2009 and 2021 (Kasprak et al. 2026). In these two study areas, a supervised vegetation classification was performed on imagery from 2009, 2014, and 2021, and landcover between these years compared four high-level groupings: water, rock or sand, stressed vegetation, and green vegetation, which included species such as tamarisk, cottonwood, willow, and seepwillow. Green vegetation colonized recently exposed areas, but as water elevations continued to fall, the green vegetation began to show signs of water stress visible in the imagery (such as browning and defoliation).

Two special status plant species are present in the Lake Powell reach and could be affected by operations (**TA 9 Attachment 1**).

TA 9.1.2 Glen Canyon Dam to Lake Mead

Marsh, woody riparian, and upland habitats from Glen Canyon Dam to Lake Mead are influenced by the peak magnitudes, daily fluctuations, and seasonal patterns of river flows. Vegetation composition, structure, distribution, and function are closely tied to ongoing Glen Canyon Dam operations (**Table TA 9-1**; Reclamation 2016; Palmquist et al. 2023).

Hydrologic zone (active channel and active floodplain) was consistently the strongest predictor of vegetation between Glen Canyon Dam and Lake Mead (Palmquist et al. 2023). The active channel, which is inundated by daily fluctuating flows up to 25,000 cubic feet per second (cfs), supports both marsh habitat and woody riparian habitat. Marsh habitat includes species such as bulrushes, rushes (*Juncus* spp.), horsetails (*Equisetum* spp.), and common reed. Woody riparian habitat includes species such as seep willows (*Baccharis* spp.), willow (*Salix* spp.), tamarisk, arrowweed (*Pluchea sericea*), and honey mesquite (*Prosopis glandulosa*). These species occupy the main river margin as well as return-current channels and successional backwaters that are inundated daily for at least part of the year. The active floodplain, inundated by flows up to 45,000 cfs during high-flow experiments (HFEs), supports woody riparian and upland habitat, which includes the woody riparian species as well as upland species, such as mesa dropseed (*Sporobolus flexulosus*), red brome (*Bromus rubens*), and spiny aster (*Chlorocantha spinosa*).

Long-term vegetation monitoring has been conducted since 2014 at two site types: 1) at random locations at sandbars, channel margins, and debris fans and 2) at fixed-site sandbars (Palmquist et al. 2018a). Vegetation dynamics between these two site types vary, including species composition and temporal patterns between years (Palmquist et al. 2023). The fixed-site sandbars are eddy sandbars that have been part of long-term monitoring for geomorphic change and are generally popular camping sites (Palmquist et al. 2018a). At both site types, native species cover and richness were greater than nonnative species cover and richness across all hydrologic zones (Palmquist et al. 2023). The National Park Service has conducted vegetation treatments at a small number of fixed-site sandbars to promote aeolian sand transfer to nearby cultural sites and create campsites for river recreation. These impacts are discussed in **TA 11**, Cultural Resources, and **TA 14,** Recreation.

Marsh and woody riparian vegetation have expanded in this reach since Glen Canyon Dam was completed in 1963 (Sankey et al. 2015). Encroachment of marsh and woody riparian vegetation has decreased the amount of unvegetated areas in the active channel and active floodplain. The greatest area of vegetation expansion between 2002 and 2013 was woody riparian vegetation (tamarisk and seep willow) on sandbars in the active channel (Durning et al. 2021). Encroachment of woody riparian vegetation was most prevalent in the higher elevations of the active channel due to the lower elevation areas being inundated regularly enough to prevent vegetation encroachment. This was despite HFEs in 2004, 2008, and 2012, which aimed to increase unvegetated areas on sandbars for recreation. The effectiveness of HFEs in inhibiting vegetation encroachment is dependent on several factors, including existing vegetation stabilization, geomorphic setting, sandbar elevation, river segment, duration, and flow volume (Mueller et al. 2018; Hazel et al. 2022).

The availability of water at low river elevations (e.g., below 25,000 cfs) from consistent base flows can promote vegetation establishment closer to the river where there were historically bare sand beaches, whereas prolonged periods of peak flow (e.g., above 40,000 cfs during an HFE) may inhibit vegetation establishment closer to the river through scouring action. When inundation frequency increased by five percent or more, vegetation expansion closer to the river was unlikely to occur (Sankey et al. 2015). HFEs may also reduce the narrowing of the riparian zone by inundating the riparian plants that are currently dying back at the upper end of the riparian zone. The Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement (2024 LTEMP SEIS) allows for more spring HFEs to occur in the future, which may

allow more HFEs to occur at the historic timing at which peak flows occurred in this system prior the building of the Glen Canyon Dam (Reclamation 2024) which may have benefits for LTEMP vegetation goals both closer to the river and at the upper end of the riparian zone.

Additional factors related to flow that influence marsh and woody riparian vegetation include characteristics of deposited sediments (e.g., water-holding capacity, aeration, and nutrient levels), depth to groundwater, and anoxia in the root zone. Sand and silt particles are critical for supporting riparian species, and continual erosion may ultimately result in the loss of large stands of riparian plants (Palmquist et al. 2025). The export of sediments (particularly silts, clays, and organic matter) was observed to coarsen substrates, affect nutrient concentrations, and reduce opportunities for subsequent recruitment of tamarisk and native shrubs such as coyote willow (*Salix exigua*) and Emory seep willow (*Baccharis emoryi*; Reclamation 2016).

Twenty special status plant species are present in the Grand Canyon to Lake Mead reach and could be affected by operations (**TA 9 Attachment 1**).

TA 9.1.3 Lake Mead

Similar to Lake Powell, short- and long-term fluctuations in water elevation affect the shoreline vegetation of Lake Mead (**Table TA 9-1**) and are described in detail in Section 3.4 and Section 3.8.1 of the LCR MSCP Habitat Conservation Plan (HCP; Reclamation 2004a) and Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (2007 Final EIS; Reclamation 2016). The median annual water elevation fluctuation between 2008 and 2025 was approximately 16.19 feet (**Figure TA 9-3**). The drawdown of Lake Mead from 1998 to 2011 reduced the lake's perimeter by more than 400 kilometers (249 miles) and exposed more than 61,776 acres of formerly submerged land (Engel et al. 2014). Water levels have continued to decline since 2012 (see **Figure TA 3-5**, in **TA 3**, Hydrologic Resources), further reducing the lake's perimeter and exposing additional shoreline.

Historically, Lake Mead has undergone large changes in elevation that create and subsequently flood both marsh and woody riparian habitat. From 1990–1996, Lake Mead reservoir levels remained within a relatively narrow range (**Figure TA 3-5, TA 3**, Hydrologic Resources), creating dense stands of willow habitat (approximately 1000 acres; McKernan and Braden 1998). When the water levels rose, then dropped from 2000–2004, a delta at the Virgin River was created that changed habitat conditions, resulting in a subsequent die off of willow (Reclamation 2004b).

Riparian vegetation that does develop within the range of Lake Mead elevation fluctuations is temporary, as fluctuating lake elevations either dewater or inundate these areas through time. Vegetation that develops within the range of short-term (interannual) Lake Mead elevation fluctuations is likely temporary, as frequent inundation and dewatering prevent long-term establishment. Long-term fluctuations allow the establishment of woody riparian vegetation (primarily tamarisk); however, as lake levels continue to fall, tamarisk may begin to show drought stress and mortality when water levels fall below their roots. The decline of tamarisk has been correlated with increased root exposure above the waterline; cover and density of tamarisk were substantially reduced after 6 years of exposure (Engel et al. 2014). Overall, native species cover has

been found to be greatest on surfaces that have been exposed for a longer period of time (Engel et al. 2014).

Sediment deposition and associated vegetation growth at the Lake Mead delta have been ongoing for decades. Historically, both marsh and woody riparian habitats were limited, even along much of the historic Colorado River corridor now inundated by Lake Mead (Engel et al. 2014). The highest concentration of vegetated habitat occurs in the Colorado and Virgin River deltas.

Native vegetation at Lake Mead has also been positively influenced by defoliation from the tamarisk leaf beetle (*Diorhabda* spp.; beetle). Beetles were released along the Virgin River in St. George, Utah, in 2006, and widespread defoliation of tamarisk was first observed in St. George in 2008. The area of tamarisk defoliation on the Virgin River expanded downstream annually, encompassing the entire stretch of the Virgin River to Lake Mead, Nevada, by the end of 2012 (Gonzalez et al. 2020). Arrowweed was found to replace defoliated tamarisk stands as the dominant species along the Virgin River floodplain, increasing native species cover (Gonzalez et al. 2020). Additional control efforts by the National Park Service Lake Mead Inter-Regional Invasive Plant Management team have contributed to controlling tamarisk in the Lake Mead National Recreation Area (NPS 2022).

Twenty-one special status plant species are present in the Lake Mead reach and could be affected by operations (**TA 9 Attachment 1**).

TA 9.1.4 Hoover Dam to SIB

Vegetation in this reach is described in detail in Section 3.4 and Section 3.8.1 of the LCR MSCP HCP and 2007 Final EIS (Reclamation 2004a; Reclamation 2016). The LCR MSCP planning area identifies fourteen land-cover types, including five woody riparian types that are divided into multiple structural types, and the marsh land cover type is divided into seven compositional types based on plant composition and vegetation structure (**Table TA 9-2**). The LCR MSCP HCP further describes the extent of these habitat types by river reach in Table 3-8 and Figures 3-2 through 3-8 (Reclamation 2004a), which are incorporated by reference.

Table TA 9-2
Summary of Vegetation Cover Types from Lake Mead to the SIB

Vegetation Type	Characteristics
Marsh	Cattail/bulrush, little common reed, trees and grasses, and open water
Woody Riparian	Cottonwood-willow, tamarisk, honey mesquite, tamarisk-screwbean mesquite, arrowweed, atriplex
Upland	Desert scrub, agriculture, developed

Source: Reclamation 2004a

Marsh and woody riparian vegetation can be formed through either direct connection to the river and river-dependent groundwater or along reservoirs and impoundments (e.g., Lake Havasu and Mittry Lake). The dams in this reach and their resultant reservoirs and flood control structures, including levees, have altered the extent and quality of marsh and woody riparian vegetation along the river and have converted large areas of riverine habitat to lacustrine habitat behind dams and

diversion facilities (Reclamation 2004a). Habitats at wildlife refuges and management areas, restoration areas, and LCR MSCP conservation areas are dependent on water diversions from the river and existing groundwater levels supported by the river's surface elevation to establish and maintain woody riparian and marsh habitat.

Since the beetle's release in 2006, its range has expanded downstream from Lake Mead along the lower Colorado River, and by 2019, large beetle populations were detected along the Imperial stretch of the lower Colorado River. In 2020, beetles were present, and defoliation was documented in or around all LCR MSCP study areas (Reclamation 2021), and in 2024 beetles have been documented to the SIB (McLeod and Pellegrini 2021; Mahoney et. al 2022; RiversEdge West 2025).

The LCR MSCP HCP and subsequent BOs set habitat creation goals to mitigate for predicted impacts from covered river operations, including flow reductions, water delivery and diversion, changes in point of diversion, generation of hydropower, and operation and maintenance activities in the LCR MSCP planning area (Reclamation 2004a; FWS 2005, 2018, 2022, 2024). A summary of the habitat creation goals and habitat created towards those goals as of 2025 (LCR MSCP 2025) is included as **Table TA 10-1**, in **TA 10**, Terrestrial Wildlife Including Special Status Species. Habitat creation goals assumed the predicted habitat impacts from reductions in flow and changes in points of diversion up to 2.083 maf per year may occur annually until 2055 and would be permanent, even if impacts never actually occur. Habitat would be created to replace it in LCR MSCP conservation areas. This includes a prediction that all existing cottonwood-willow land cover supported by the river and river connected groundwater would be lost due to flow-related covered activities (with the exception of habitat at Topock Marsh and Lake Havasu). Impacts on marsh from flow reductions from 2.083 maf per year to 3 maf per year were predicted to be short term in duration, and the habitat would recover when inundated again (FWS 2024).

Table TA 9-3
Summary of Habitat Creation Goals and Acres Created from Lake Mead to the SIB

Habitat Type	Habitat Creation Goal[1]	Acres Created through 2025[2]
Marsh	568	362
Woody Riparian (cottonwood-willow only)	5,940	4,954
Woody Riparian (honey mesquite only)	1,320	2,046
Woody Riparian (total)	7,260	7,000

Source: [1]Reclamation 2004a; FWS 2005, 2022, 2024; [2]LCR MSCP 2020, 2025

In 2024, the Bureau of Reclamation (Reclamation) contracted RiverRestoration.Org, LLC to map backwater areas (water, marsh, and non-marsh) in the LCR MSCP planning area and to conduct a change analysis between the 2024 effort and a previous 2000 backwater mapping effort. The study found an overall decrease in marsh between Davis Dam and Morelos Dam from 2000 to 2024. The change from marsh to non-marsh was most common and is likely a response to prolonged drought conditions (RiverRestoration.Org 2025). Non-marsh includes woody riparian and upland vegetation types, as well as a broader range of dry and vegetated features that would not typically be considered

"upland" in a geomorphic or ecological sense, such as dry arroyos, cleared ground, and fringe riparian areas.

Nine special status plant species are present in the Hoover Dam to SIB reach and could be influenced by operations (**TA 9 Attachment 1**).

TA 9.2 Environmental Consequences

TA 9.2.1 Methodology

Lake Powell

Ground-based vegetation mapping has not been conducted for all of Lake Powell's shoreline (NPS 2023). To estimate the extent of marsh, woody riparian, and upland habitats within the full pool area of Lake Powell, mapping data from the vegetation classification and mapping project for Glen Canyon National Recreation Area and Rainbow Bridge National Monument was used (NPS 2014; Tendick et al. 2017). This vegetation classification map was created using 1,164 vegetation classification plots, 51 observation points, and aerial photointerpretation using 2009 and 2010 National Agriculture Imagery Program imagery (Tendick et al. 2017). Woody riparian vegetation classes included coyote willow shrublands, Fremont cottonwood woodland, relict spring-supported mixed deciduous woodlands and shrublands, and tamarisk shrublands. The only marsh vegetation class present was spring-supported herbaceous vegetation. As noted in **TA 9.1.1**, since 2011, approximately 59,000 additional acres of formerly submerged land has been exposed in addition to 26,188 acres of terrestrial habitats described in **Table TA 9-2**.

There are no long-term vegetation monitoring datasets available for Lake Powell that would support quantitative habitat modeling for this reach, as was done for the Glen Canyon to Lake Mead section; therefore, a qualitative approach was used to determine the predicted differences in marsh and woody riparian vegetation among the alternatives. As noted in **TA 9.1**, marsh and woody riparian vegetation are affected by water level fluctuations on short (annual) and long (5-year) time scales. Therefore, changes in water elevation over one-year and five-year periods were used as proxies to represent potential changes to marsh and woody riparian vegetation. In the Lake Powell reach, potential changes to marsh and native woody riparian vegetation would be primarily restricted to tributary side canyons and emerging riverine habitats along the major rivers, while non-native woody riparian vegetation (tamarisk) would be expected to continue to establish along the reservoir shoreline.

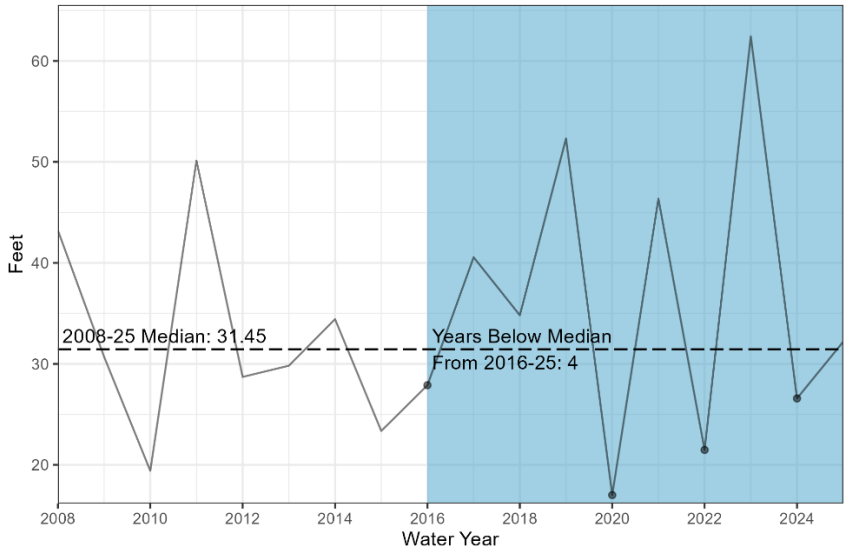
To determine the changes in water elevation under each alternative, the Colorado River Simulation System model was applied within the Decision Making under Deep Uncertainty (DMDU) framework to show maximum variability within 1 year and over 5 years in robustness heat map figures. A 5-year period was selected to represent longer-term variability in water level fluctuations. The modeled variability from the CRSS model and the DMDU framework were then compared to historic conditions to determine whether variability would remain the same, increase, or decrease for each alternative. For the purposes of this analysis, historic conditions extend from water year (WY) 2008–2025 (the 2007 Interim Guidelines period). Refer to **Section 3.2**, Analysis Methods, for

additional information on DMDU and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU robustness heatmaps.

The DMDU calculations are based on alternatives meeting a preferred minimum performance, defined by a threshold applied to model output values and a frequency over time. If a modeled future meets both the threshold and frequency, it is considered a successful future. For Lake Powell vegetation, the thresholds correspond to the median observed variability in water elevation over 1-year (for marsh vegetation) and 5-year (for woody riparian vegetation), representing historic conditions (**Figure TA 9-1** and **Figure TA 9-2**). The Continued Current Strategies (CCS) Comparative Baseline data displayed on each figure represents the modeled outcome if current management strategies were continued into the future. This information is included for comparative purposes between the alternatives and the modeled future of the analysis area.

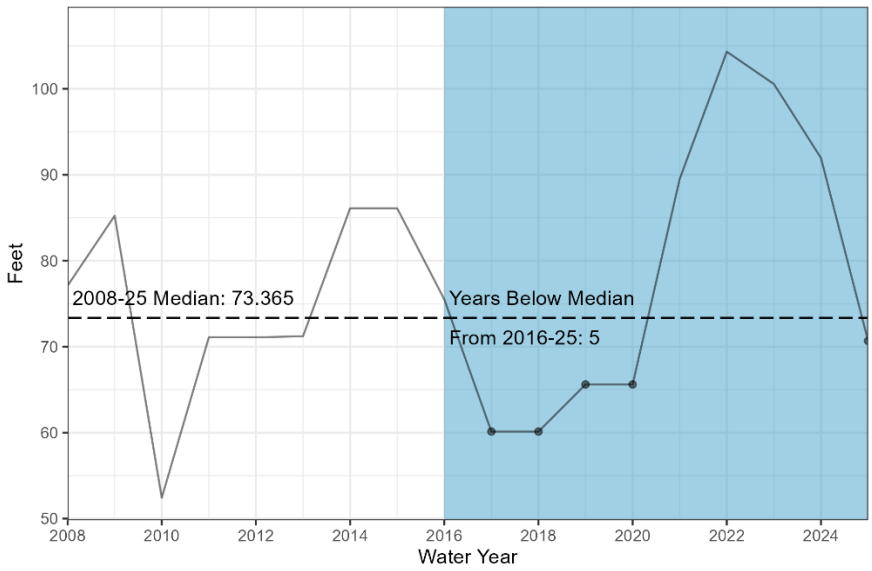
Since vegetation can tolerate a range of environmental conditions, failing to meet the threshold criteria once over the full modeling period is not necessarily detrimental to the habitat's establishment or growth over the long-term. Therefore, the analysis focuses on the number of times that the model meets the criteria over a 10-year window for marsh and a rolling 10-year window for woody riparian vegetation.

Figure TA 9-1
Historical Maximum Annual Water Elevation Change in Lake Powell



Note: The median of the maximum annual change was calculated for the 2007 Interim Guidelines period from 2008 to 2025. The number of years in which the maximum annual change was below that median (31.45 feet) in the last 10 years (2016–2025) was counted to determine the historical frequency. The full time period on **Figure TA 9-1** shows the entire 2007 Interim Guidelines period, while the shaded area indicates the last 10 years.

Figure TA 9-2
Historical Maximum 5-year Elevation Change in Lake Powell



Note: The maximum 5-year elevation change for each year was calculated using the minimum and maximum change from the previous 5 years. For example, the 5-year change for 2021 was calculated by using the minimum and maximums from 2016-2021. The median of the maximum 5-year change was calculated for the 2007 Interim Guidelines period from 2008 to 2025. The number of years in which the maximum 5-year change was below that median (73.365 feet) in the last 10 years (2016–2025) was counted to determine the historical frequency. The full time period on **Figure TA 9-2** shows the entire 2 Interim Guidelines period, while the shaded area indicates the last 10 years.

Glen Canyon Dam to Lake Mead

Riparian species classification data from Durning et al. (2018) was used to quantify existing land cover of marsh, woody riparian, and upland habitats in the analysis area of this reach. Durning et al. used remote sensing to delineate 33 species assemblages, which were consolidated based on the dominant species into marsh, woody riparian, and upland. Using the modeled and estimated 45,000 cfs stage elevation, there are approximately 3,076 acres of terrestrial habitat present in the analysis area (**Table TA 9-1**).

The Grand Canyon Monitoring and Research Center conducted hydrological niche modeling for several species on the fixed site sandbars for each alternative and used these models to estimate the acres of habitat suitability for each species (**Figure TA 9-9** and **Figure TA 9-10**; Butterfield and Palmquist 2026). The data used for this modeling was collected from 2014 to 2019 (Palmquist et al. 2018a) and can be accessed in the associated data release (Palmquist et al. 2022). In addition to habitat suitability, changes to native species richness (**Figure TA 9-12**), proportion native cover (**Figure TA 9-13**), and total vegetation cover (**Figure TA 9-14**) were estimated by combining the modeled habitat suitability. The hydrological niche modeling includes HFEs. For a detailed analysis of frequency and duration of HFEs under each alternative, see **TA 5**, Geomorphology and Sediment Resources.

Figures presented for this reach are conditional box plots. Refer to **Section 3.2**, Analysis Methods, for additional information on DMDU and **Appendix E**, DMDU Overview and Approach, for an

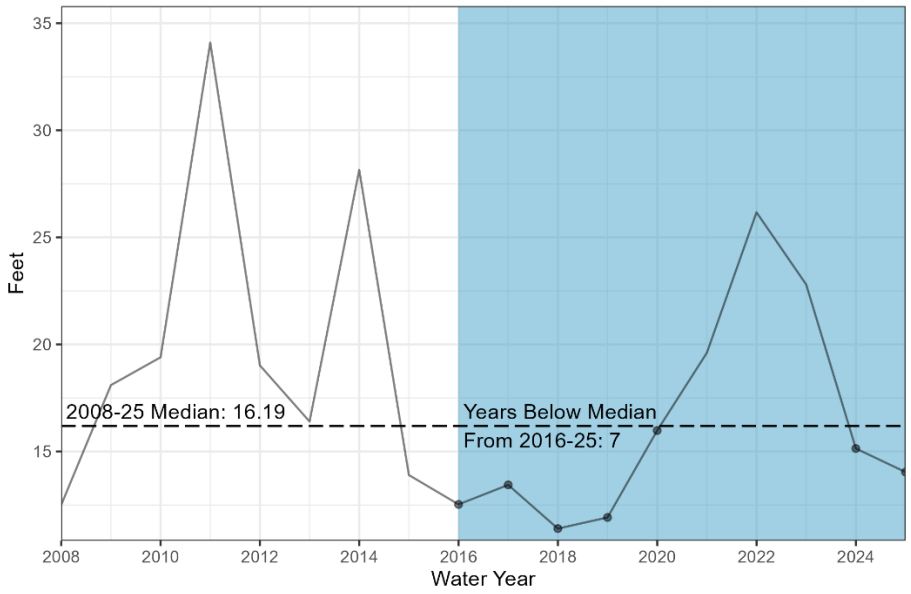
overview of how to interpret the DMDU conditional box plots. The hydrological niche modeling results used to create these figures can be accessed in the associated data release (Butterfield and Palmquist 2026). Habitat suitability is modeled in **Figure TA 9-9** and **Figure TA 9-10**, species included were consolidated by marsh (*Schoenoplectus* spp., *Juncu*s spp., *Equisetum arvense*, and *Phragmites australis*; **Figure TA 9-9**) and woody riparian (*Baccharis* spp., *Pluchea sericea*, *Prosopis glandulosa*, and *Salix exigua*; **Figure TA 9-10**). Upland species were not modeled because upland habitat is considered ubiquitous within and surrounding the analysis area (**Table TA 9-1**). Since multiple species can have similar habitat suitability characteristics, the acres presented in **Figure TA 9-9** and **Figure TA 9-10** are likely an overestimate and should be used to compare alternatives relatively in terms of increasing or decreasing habitat rather than as a prediction of actual acres under each alternative. The dashed lines included in **Figure TA 9-9** through **Figure TA 9-14** are reference lines to the 50th percentile of the modeled 'historical' period, which were modeled using 2000-2025 hydrology under CCS Comparative Baseline using a dry-initial condition (see **Section 3.2.6**, Decision Making under Deep Uncertainty for an explanation of initial conditions).

Lake Mead

In 2018, Reclamation contracted Sound Science, LLC, to classify and map riparian vegetation along the lower Colorado River, including Lake Mead (Sound Science 2025). Publicly available aerial imagery and Google Earth Engine were used to classify the imagery into eight classes: Cottonwood/Willow, Tamarisk, Mesquite, Marsh, other (sparsely vegetated), other (densely vegetated), water, and bare ground. Agricultural and developed areas were excluded from this classification. These classes were consolidated into woody riparian (Cottonwood/Willow, Tamarisk, Mesquite, other [densely vegetated]), marsh, and upland (other [sparsely vegetated], bare ground). Within the full pool area of Lake Mead, there are approximately 71,250 acres of terrestrial habitats present (**Table TA 9-1**).

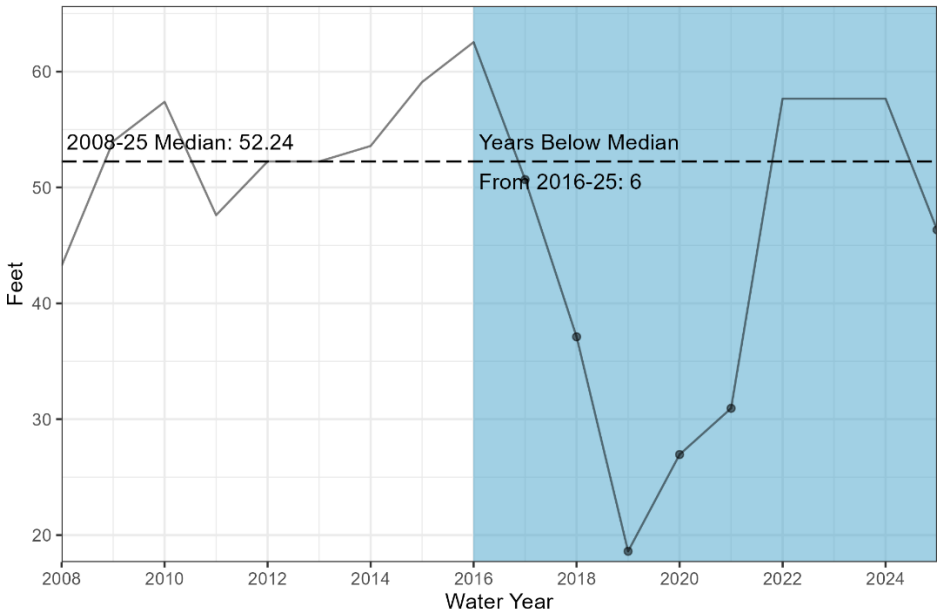
Similar to Lake Powell, changes in water elevation from historical conditions were used as a proxy to determine potential impacts on marsh and woody riparian vegetation under each alternative (**Figure TA 9-3** and **Figure TA 9-4**). The same methods for Lake Mead were used as described for Lake Powell.

Figure TA 9-3
Historical Maximum Annual Water Elevation Change in Lake Mead



Note: The median of the maximum annual change was calculated for the 2007 Interim Guidelines period from 2008 to 2025. The number of years where the max annual change was below that median (16.19 feet) in the last 10 years (2016–2025) was counted to determine the historical frequency. The full time period on **Figure TA 9-3** shows the entire Interim Guidelines period, while the shaded area indicates the last 10 years.

Figure TA 9-4
Historical Maximum 5-year Elevation Change in Lake Mead



Note: The maximum 5-year elevation change for each year was calculated using the minimum and maximum change from the previous 5 years. For example, the 5-year change for 2021 was calculated by using the minimum and maximums from 2016 to 2021. The median of the maximum 5-year change was calculated for the 2007 Interim Guidelines period from 2008 to 2025. The number of years where the

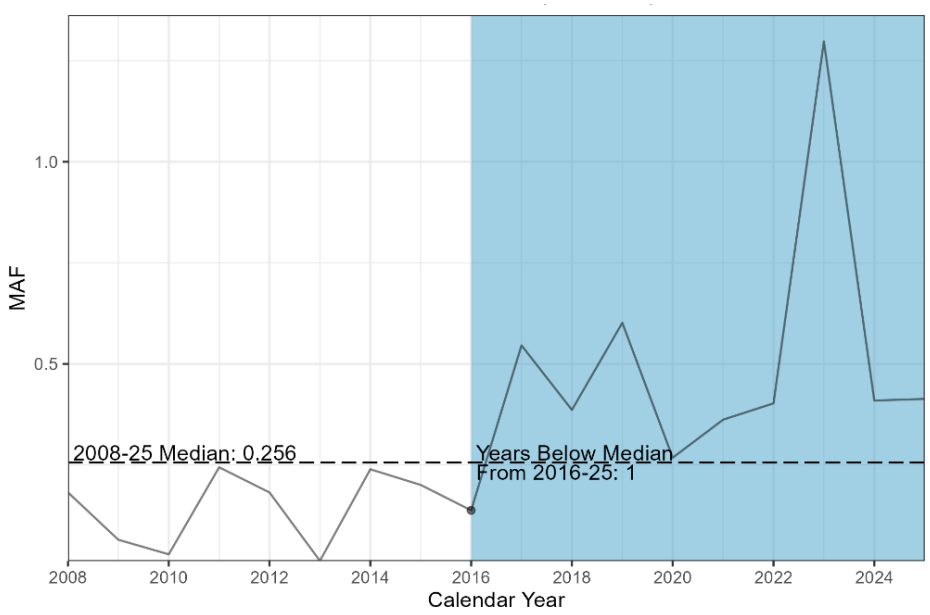
maximum 5-year change was below that median (52.24 feet) in the last 10 years (2016–2025) was counted to determine the historical frequency. The full time period on **Figure TA 9-4** shows the entire Interim Guidelines period, while the shaded area indicates the last 10 years.

Hoover Dam to Southerly International Boundary

The Sound Science, LLC riparian vegetation mapping effort described above under Lake Mead also includes the analysis areas within the Hoover Dam to SIB reach (Sound Science 2025). Within the full pool of Lake Mohave and Lake Havasu, and the historical floodplain of the Colorado River from Hoover Dam to the SIB, there are approximately 55,121 acres of terrestrial habitat (**Table TA 9-1**).

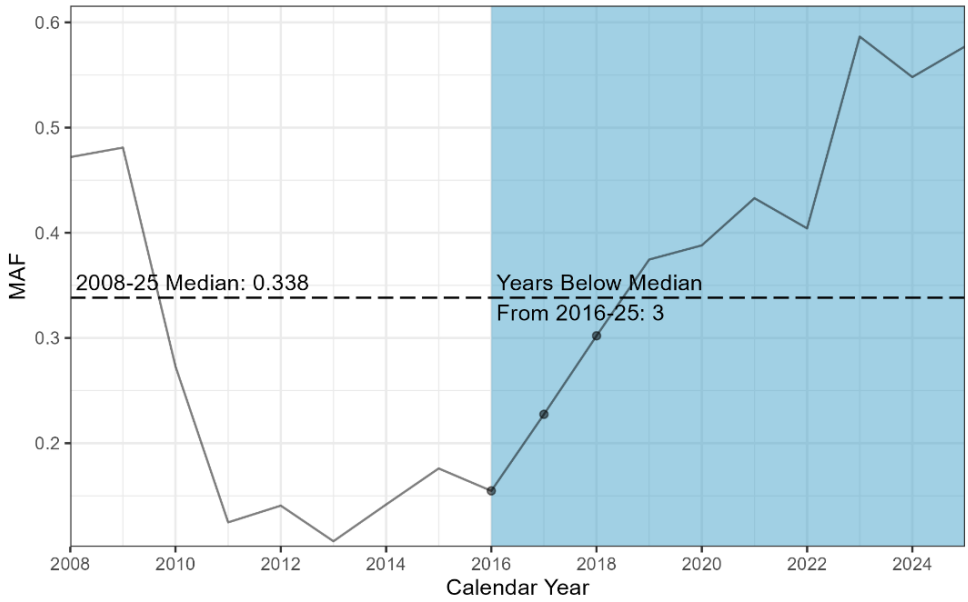
Similar to Lake Powell and Lake Mead, changes in water elevation were used as a proxy to determine potential impacts on marsh and woody riparian vegetation under each alternative. However, for this reach, water releases were used to represent changes from historic conditions rather than water elevation (**Figure TA 9-5** and **Figure TA 9-6**). Releases from Hoover Dam, Davis Dam, and Parker Dam were modeled, as releases from these dams determine the amount of water available downstream. Davis Dam and Parker Dam were found to have similar trends as Hoover Dam; therefore, only Hoover Dam results are discussed in detail (see **TA 9 Attachment 2** for Davis and Parker Dam results). The impacts as described in the Hoover to SIB section apply to the entire reach.

Figure TA 9-5
Historical Change in Annual Water Releases from Hoover Dam



Note: The median annual change was calculated from 2008 to 2025, whereas the number of years in which the change was below that median was calculated for the prior 10 years (shaded).

Figure TA 9-6
Historical Change in the Average 5-year Water Releases from Hoover Dam



Note: The median 5-year water release was calculated from 2008 to 2025, whereas the number of years in which the change was below that median was calculated for the prior 10 years (shaded).

Impact Analysis Area

Lake Powell

The Lake Powell reach includes Lake Powell up to full pool (water surface elevation 3,700 feet).

Glen Canyon Dam to Lake Mead

The Glen Canyon Dam to Lake Mead reach extends from Glen Canyon Dam (river mile [RM] -15.6) to RM 240. This reach includes the Colorado River through the Grand Canyon and ends where Lake Mead at full pool occurs at RM 240. The analysis area for this reach extends to the 45,000 cfs modeled stage elevation, corresponding to the maximum controlled flood releases under the current HFE protocol, and is considered the active floodplain of the Colorado River in this reach (LTEMP 2016). The modeled 45,000 cfs stage elevation from Magirl et al. (2008) was used for Lees Ferry (RM 0) to Diamond Creek (RM 226) and was estimated using the maximum height of the modeled stage elevation for RM 15.6 to RM 0 and RM 226 to RM 240.

Riparian vegetation composition changes from Glen Canyon Dam to Lake Mead and is related to decreasing elevation, increases in temperature, and shifts in precipitation (Palmquist et al. 2018b). The section from Glen Canyon Dam to Lake Mead is divided into three sub-reaches to account for these vegetation community changes: Marble Canyon (RM -15.6 to RM 60), Eastern Grand Canyon (RM 60 to RM 161), and Western Grand Canyon (RM 161 to RM 240).

Lake Mead

The Lake Mead reach extends from RM 240 in Grand Canyon to Hoover Dam. The analysis area for this reach includes full pool of Lake Mead (water surface elevation 1,229 feet).

Hoover Dam to SIB

The Hoover Dam to SIB reach is aligned with the LCR MSCP planning area. As described in **TA 8**, Biological Resources – Fish and Other Aquatic Species, there are seven reaches within the LCR MSCP planning area. For vegetation analysis, the analysis area includes LCR MSCP reaches 2-7 (Reclamation 2004a). Reach 1 in the LCR MSCP planning area includes Lake Mead up to full pool, which is addressed in the section above under Lake Mead. The analysis area includes the full pool of Lake Mohave and Lake Havasu and the historical floodplain of the Colorado River.

Assumptions

- A change of 10 percent between/among alternatives is considered a notable difference for the DMDU analysis.
- Upland, marsh, and woody riparian vegetation are suitable representatives for the major vegetation types found throughout the analysis area.
- A change in water elevations or releases greater than what has been observed over the past 10 years would result in changes to marsh and woody riparian vegetation compared to existing conditions.

Impact Indicators

- A change in the median and interquartile ranges from modeled historic conditions (Glen Canyon Dam to Lake Mead reach).
- Changes in water fluctuations within a single year compared to historic conditions (Lake Powell, Lake Mead, and Hoover Dam to SIB reaches).
- Changes in water fluctuations in the preceding 5 years compared to historic conditions (Lake Powell, Lake Mead, and Hoover Dam to SIB reaches).

TA 9.2.2 Issue 1: How would changes in the management of the Colorado River impact vegetation, including for special status species

Lake Powell

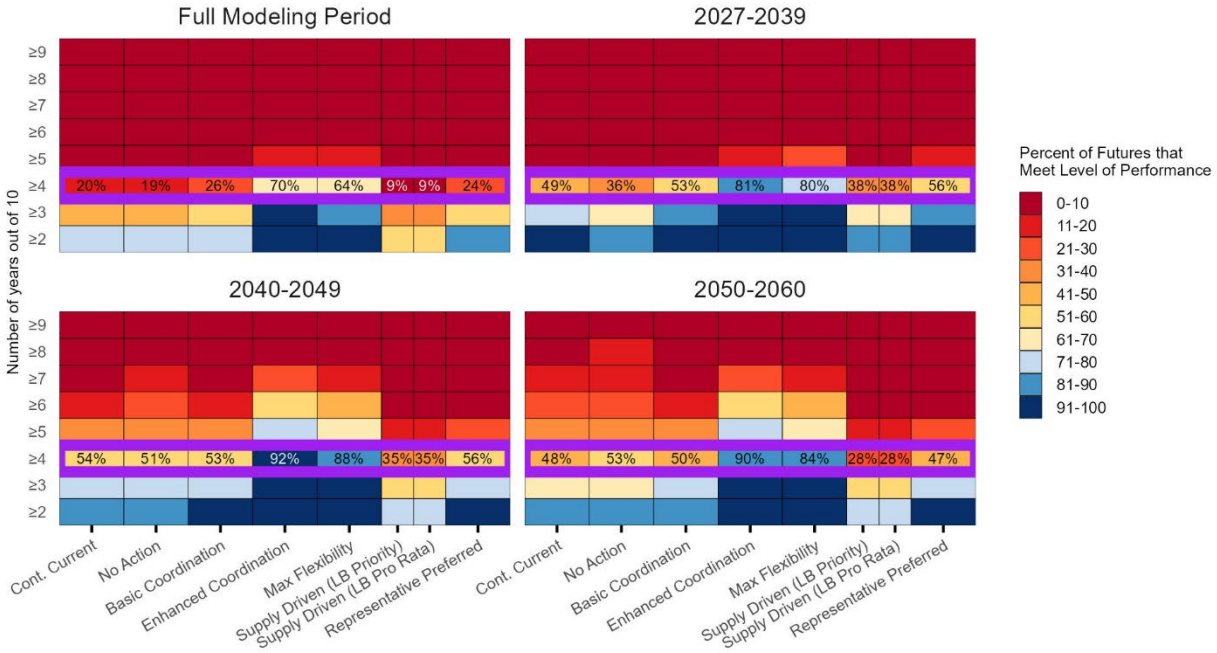
Marsh Vegetation

As described above in **TA 9.2.1**, there are no long-term vegetation monitoring datasets available for Lake Powell that would support quantitative habitat modeling, therefore, changes in water elevation over one-year and five-year periods were used as proxies to represent potential changes to marsh and woody riparian vegetation. The median of the maximum annual change in water surface elevation from water year (WY) 2008–2025 was 31.45 feet (**Figure TA 9-1**). Over the past 10 years (WY 2016–2025) the maximum annual change in water surface elevation was less than 31.45 feet in 4 of 10 years (**Figure TA 9-1**). These data were used to characterize the existing variability in Lake Powell that has led to the current extent of marsh vegetation in the Lake Powell analysis area and are collectively referred to as historic conditions. As described above in **TA 9.1.1** and **TA 9.2.1**, marsh vegetation in Lake Powell is primarily restricted to tributary side canyons and emerging riverine habitats along the major rivers, so potential changes to marsh vegetation would be expected to be limited to those areas. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, an alternative must have a

maximum annual change in water surface elevation of less than 31.45 feet in 4 or more years out of 10. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 4 years row is the alternative most similar to historic conditions. **Figure TA 9-7** compares the similarity of each alternative to the historic maximum annual change in Lake Powell elevation.

The other rows outside the greater than or equal to 4 years row demonstrate how many times the alternative had a maximum annual change in water surface elevation of less than 31.45 feet for X number of years, where the value of X varies by row (displayed on the y-axis). This information demonstrates whether the alternatives would meet the criterion for more or fewer years compared to historic conditions. For comparative purposes, each alternative is compared relative to historic conditions, which are outlined in the greater than or equal to 4 years row for reference. The percentages are provided in the greater than or equal to 4 years row to differentiate between alternatives, with a difference greater than 10 percent considered notable.

Figure TA 9-7
Lake Powell Marsh Riparian Vegetation: Robustness.
Percent of futures in which the maximum annual change in Lake Powell elevation is less than 31.45 feet in the number of years specified by each row during any 10-year period



The maximum annual change in water elevation for marsh over any 10-year period was calculated using historical data for the first 9 years of modeling on a rolling basis. After the 9th year, all data used to calculate the max annual change in water elevation included only modeled outputs. Since the years 2016 through 2019 included 3 years where the elevation change was greater than 31.45 feet (**Figure TA 9-1**), the early years of the first decade (2026–2029) had limited ability to reach the desired level of performance, as they could only fail one more time over the decade before failing to

reach the desired level of performance. Once the years 2016 through 2019 were excluded (2030 and beyond), it became easier for the modeled alternatives to meet the desired level of performance.

For all alternatives except for the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative, increased variability in the first decade (2027–2039; **Figure TA 9-7**) compared to modeled historic conditions, indicated by a lower percentage of futures meeting the level of performance, would result in changes in marsh vegetation. Whether an area experiences an increase or a decrease in marsh habitat in response to changed conditions is mostly dependent on local topography, but generally, an increase in variability is expected to result in a decrease in marsh vegetation due to more frequent dewatering and inundation. In the first decade, the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative are the most robust, meeting the minimum level of performance in 81 percent and 80 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 49 percent and 36 percent of futures, respectively.

For alternatives with increased variability, in the first decade, cover of prickly Russian thistle may increase due to the increased area of upland habitat created during water elevation fluctuations. Cover of prickly Russian thistle would be expected to decrease in the later decades if variability also decreases, indicated by a higher percentage of futures meeting the level of performance, reducing areas vulnerable to invasive species establishment on an annual basis. Native vegetation can re-establish over time, particularly in areas exposed for more than 3 years (Arens 2023).

In the later decades (2040–2049 and 2050–2060; **Figure TA 9-7**), the Enhanced Coordination Alternative is the most robust, meeting the minimum level of performance in 92 percent and 90 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 54 percent and 48 percent, and 51 percent and 53 percent of futures, respectively. As variability becomes closer to historic conditions for Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative (as indicated by a higher percentage of futures meeting the level of performance), marsh vegetation may re-establish to a similar historical extent under those alternatives.

For the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative under the Critically Dry Flow Category Lake Powell has a modeled WY minimum median elevation of approximately 3,520 feet and 3,512 feet above mean sea level, respectively (see **TA 3**, Hydrologic Resources, **Table TA 3-3**), which are 38 and 46 feet below, respectively, the minimum 2024 water elevation of 3,558 feet (see **TA 3**, Hydrologic Resources, **Figure TA 3-1**). Under the Average Flow Category, Lake Powell has a WY modeled minimum median elevation of approximately 3,613 and 3,605 feet for the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative, respectively (see **TA 3**, Hydrologic Resources, **Table TA 3-4**), which are approximately 55 and 47 feet higher than the minimum 2024 water elevation. This suggests higher modeled elevations under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative under all but the driest hydrologic conditions. If water elevations gradually rise with similar levels of variability to historic conditions (**Figure TA 9-7**), marsh vegetation is expected to continue to re-establish along the new water line over time. If water elevations rise, some of the side

canyons that were exposed as Lake Powell receded may reflood, inundating native plant communities that had reemerged.

If water elevations stay the same or gradually fall with similar variability to historic conditions (**Figure TA 9-7**), marsh vegetation may re-establish to a similar extent along the new water line over time. Under these alternatives, plant communities in side canyons would remain exposed.

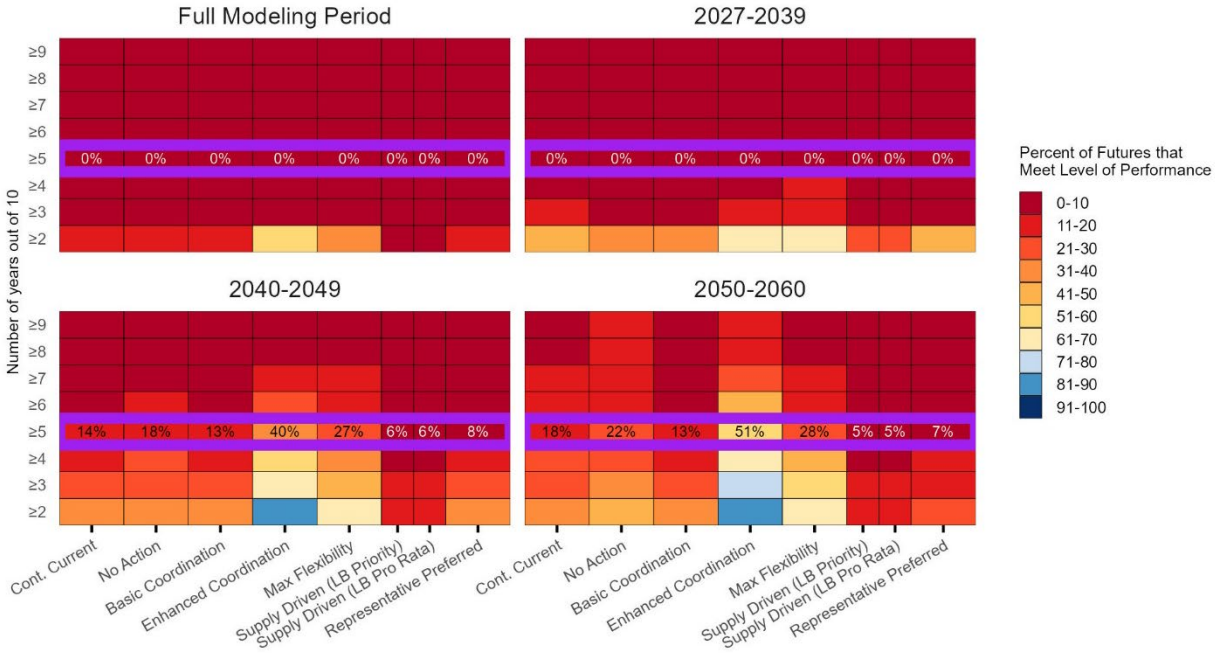
Whether water elevations rise, fall, or remain the same, if variability resembles historic conditions under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative in the later decades (**Figure TA 9-7**), marsh vegetation is expected to continue to re-establish along the new water line over time. For alternatives that have more variability than historic conditions (**Figure TA 9-7**), marsh vegetation may re-establish to a smaller extent along the new water line over time. Where variability eliminates or prevents the establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type.

Woody Riparian Vegetation

The median of the maximum 5-year change in water surface elevation from WY 2008–2025 was 73.365 feet (**Figure TA 9-8**). Over the past 10 years (WY 2016–2025), the maximum 5-year change was less than 75.51 feet in 5 of 10 years (**Figure TA 9-8**). These data were used to characterize the existing variability that has led to the current extent of woody riparian vegetation in the Lake Powell analysis area and are collectively referred to as historic conditions. As described above in **TA 9.1.1** and **TA 9.2.1**, native woody riparian vegetation is primarily restricted to tributary side canyons and emerging riverine habitats along the major rivers, while non-native woody riparian vegetation (tamarisk) is abundant in these areas as well as the reservoir shoreline. Potential changes to woody riparian vegetation would be expected to occur in both of these areas, depending on species. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, an alternative must have a maximum 5-year change in water surface elevation of less than 73.365 feet in 5 or more years during every 10-year period. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 5 years row is the alternative most similar to historic conditions. **Figure TA 9-8** compares the similarity of each alternative to the historic maximum 5-year change in Lake Powell elevation.

The trends and types of impacts on woody riparian vegetation are the same as those described for marsh vegetation for Lake Powell (**Figure TA 9-7** and **Figure TA 9-8**). Similar to marsh vegetation, the historical trend for the maximum 5-year change includes historical data for the first 9 years, which influenced the ability for the model to reach the level of performance in the first decade (2027–2039). From 2021 to 2024, all 4 years were over the median of 73.365 (**Figure TA 9-8**). Once the years 2021–2024 were no longer a part of the calculation (2034 and beyond), it became easier for the model to hit the desired level of performance, which is reflected in the second and third decades of modeling having higher percentages. In the first decade, all alternatives are equally non-robust, meeting the minimum level of performance in 0 percent of futures.

Figure TA 9-8
Lake Powell Woody Riparian Vegetation: Robustness.
Percent of futures in which the maximum 5-year change in in Lake Powell elevation is less than 73.365 feet in the number of years specified by each row during any 10-year period



In the later decades, the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative are the most robust, meeting the minimum level of performance in 40 percent and 51 percent, and 27 percent and 28 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet the minimum level of performance in 14 percent and 18 percent, and 18 percent and 22 percent of futures, respectively. The Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative would have vegetation most similar to historic conditions in the later decades (2040–2060 and 2050–2060; **Figure TA 9-8**).

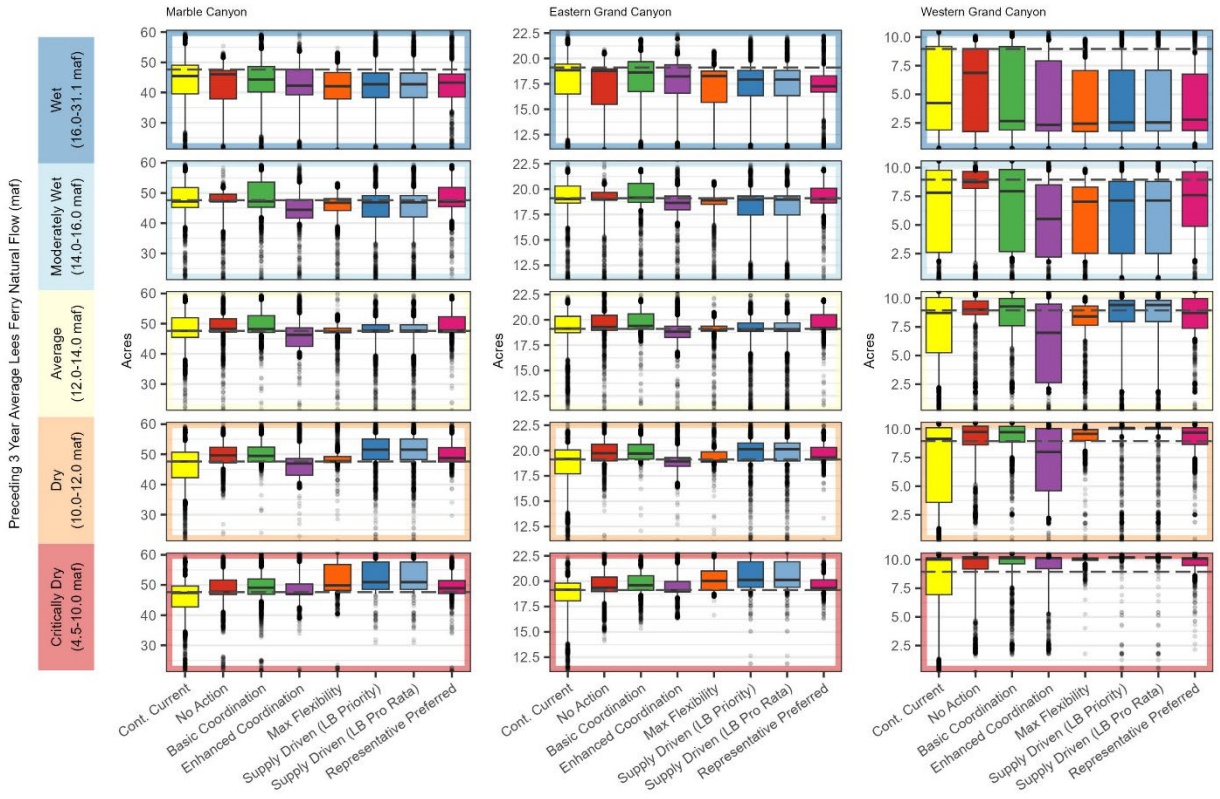
Also similar to marsh vegetation, whether water elevations rise, fall, or stay the same, if there are similar levels of variability to historic conditions under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative in the later decades (**Figure TA 9-8**), then woody riparian vegetation is expected to reestablish along the new water line over time. For alternatives that have more variability than historic conditions (**Figure TA 9-8**), woody riparian vegetation may re-establish to a smaller extent along the new water line over time. Where variability eliminates or prevents the establishment of woody riparian habitat, upland habitat may become the dominant habitat type. Whether an area experiences an increase or a decrease in woody riparian habitat in response to changed conditions is largely dependent on local topography, but generally an increase in variability is expected to result in a decrease in woody riparian vegetation.

Glen Canyon Dam to Lake Mead

Suitable Habitat Area

Marsh. Figure TA 9-9 compares the amount of modeled marsh habitat for each alternative by Grand Canyon sub-reach. Marsh vegetation includes bulrushes, rushes, field horsetail (*Equisetum arvense*), and common reed. Since multiple marsh vegetation species can have similar habitat suitability characteristics, the acres presented in **Figure TA 9-9** are likely an overestimate and should be used to compare alternatives in terms of relative increases or decreases in suitable habitat area rather than as a prediction of actual acres under each alternative. The hydrological niche modeling data used to create **Figure TA 9-9** can be found in Butterfield and Palmquist (2026).

Figure TA 9-9
Suitable Modeled Marsh Habitat for each Alternative by Sub-reach



In Marble Canyon and Eastern Grand Canyon, under the Average Flow Category, Moderately Wet Flow Category, and Dry Flow Category, the medians are near modeled historic conditions (dashed line) and the interquartile ranges are relatively restricted and overlap the modeled historic conditions (**Figure TA 9-9**) for all alternatives, indicating that the amount of habitat suitable for marsh species would likely be similar to historic conditions under these categories. Under the Critically Dry Flow Category, the Maximum Operational Flexibility Alternative, Supply Driven Alternative (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches), and Representative Preferred Alternative medians and interquartile ranges are completely above modeled historic conditions (dashed line), indicating that suitable habitat for marsh species may increase

under the Critically Dry Flow Category for those alternatives. Under the Wet Flow Category, the medians and interquartile ranges are mostly below modeled historic conditions (dashed line) for all alternatives, suggesting there would likely be less suitable marsh habitat under all alternatives.

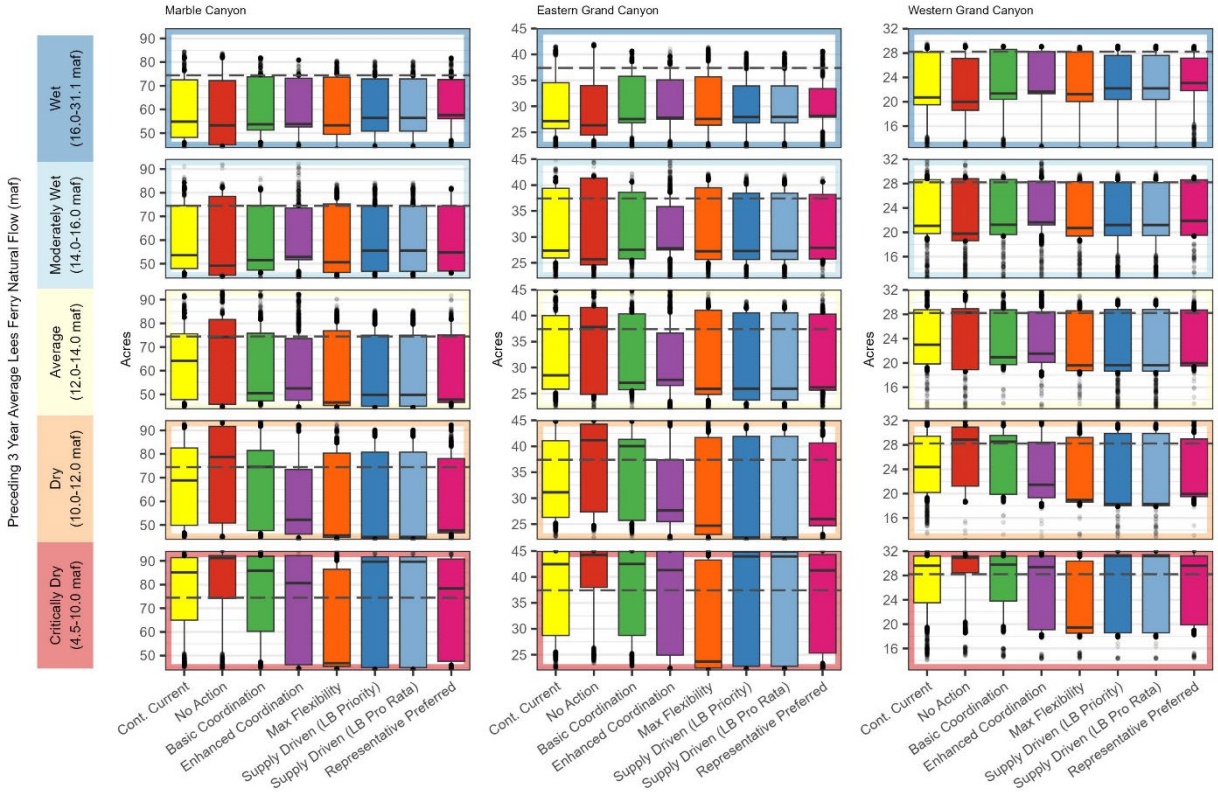
Further downstream in Western Grand Canyon, wider interquartile ranges suggest greater uncertainty in the amount of modeled suitable marsh habitat. The general trends follow that of Marble Canyon and Eastern Grand Canyon, but with more differentiation in the Moderately Wet and Dry Flow Categories; there would likely be similar levels of marsh habitat under the Average Flow Category, less marsh habitat under the Wet and Moderate Wet Flow Categories, and more marsh habitat under the Dry and Critically Dry Flow Categories. Under the Average, Dry, and Critically Dry Flow Categories, the CCS Comparative Baseline and Enhanced Coordination Alternative have wider interquartile ranges than the other alternatives, suggesting greater uncertainty.

The decrease in suitable habitat for marsh species under the Wet Flow Category for all sub-reaches and all alternatives may be because higher water levels may reduce the overall available terrestrial habitat in the active channel of the river (Sankey et al. 2015). The similarity or increase in suitable habitat for marsh species under the Dry and Critically Dry Flow Categories for all sub-reaches and all alternatives may be because decreasing water levels increase the amount of exposed shoreline habitat.

Woody Riparian. Figure TA 9-10 compares the amount of modeled woody riparian habitat for each alternative by Grand Canyon sub-reach. Woody riparian vegetation includes seep willow, arrowweed, honey mesquite, and coyote willow. Since multiple woody riparian species can have similar habitat suitability characteristics, the acres presented in **Figure TA 9-10** are likely an overestimate and should be used to compare alternatives in terms of relative increases or decreases in suitable habitat area rather than as a prediction of actual acres under each alternative. The hydrological niche modeling data used to create **Figure TA 9-10** can be found in Butterfield and Palmquist (2026).

Across all three sub-reaches, similar interquartile ranges would suggest that woody riparian suitable habitat would respond in a similar way across all alternatives under each flow category. However, the wide interquartile ranges suggest a high amount of uncertainty about how vegetation would respond under each of the modeled conditions and alternatives in all three sub-reaches.

Figure TA 9-10
Suitable Modeled Woody Riparian Habitat for each Alternative by Sub-reach



Similar to marsh habitat, under the Average, Moderately Wet Flow, Wet Flow, and Dry Flow Categories, there is less suitable habitat for woody riparian species, as indicated by the median remaining below the modeled historic conditions under all sub-reaches and across all alternatives except for the No Action Alternative and Enhanced Coordination Alternative in the Dry Flow Category. For some alternatives, the interquartile range expands above the modeled historic conditions (dashed line), indicating uncertainty about how vegetation would respond. Under the Critically Dry Flow Category, the medians are typically above the modeled historic conditions (dashed line), indicating a likely increase in suitable habitat for woody riparian vegetation under all alternatives except for the Maximum Flexibility Alternative. However, the large interquartile ranges extend far above as well as below the modeled historic conditions (dashed line) under all reaches and for all alternatives except for the No Action Alternative, indicating the variability is too high to predict whether there would be more or less suitable habitat for woody riparian species under these alternatives. The No Action Alternative remains above the modeled historic conditions for all three sub-reaches. This may be because under the No Action Alternative, there would be less water available compared to the other alternatives, and thus more exposed shoreline that can support woody riparian species.

Similar to marsh habitat, the decrease in suitable habitat for woody riparian species under the Moderately Wet Flow Category and Wet Flow Category for all sub-reaches and all alternatives may be because higher water levels reduce the overall available terrestrial habitat (Sankey et al. 2015).

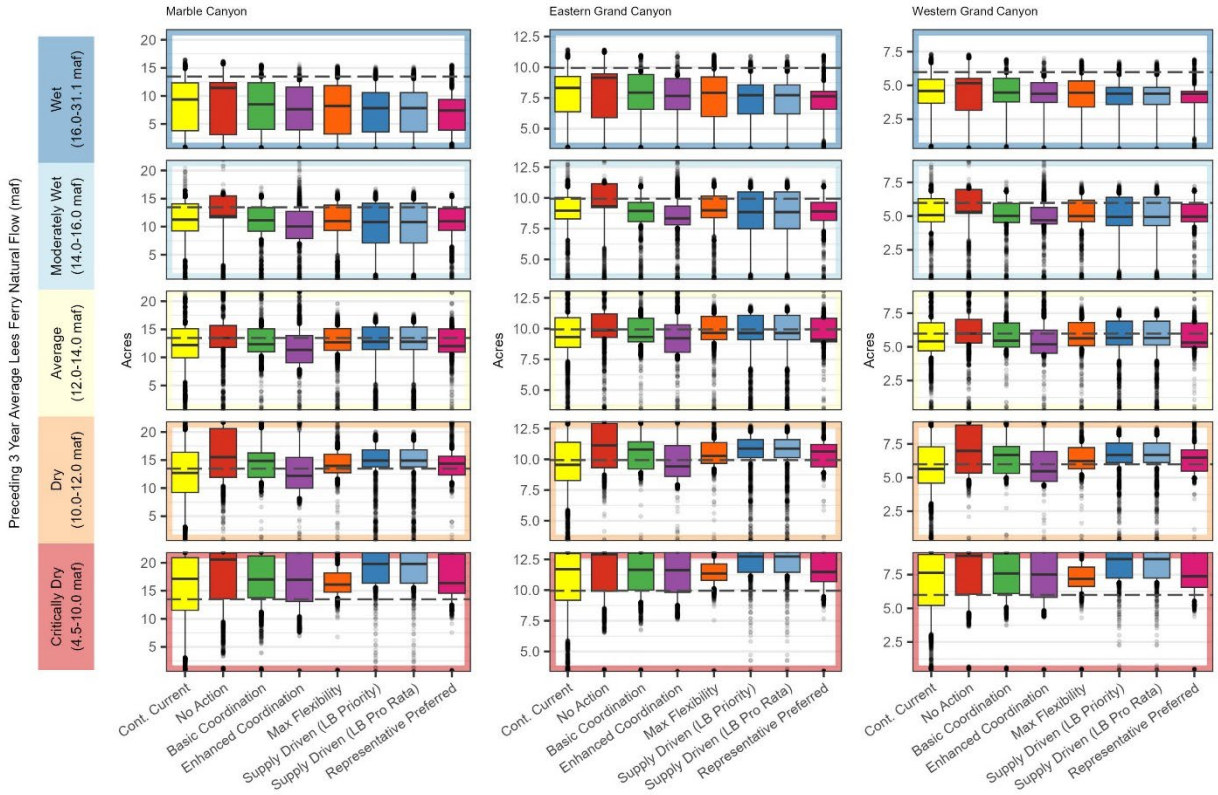
Whereas suitable habitat for woody riparian species may increase under the Critically Dry Flow Category, this expansion would occur near river level on areas recently exposed by lower water levels. Suitable habitat for both woody riparian and marsh species may overlap in these recently exposed areas, where these habitat types would compete near the river. In areas near the top of the active floodplain, decreasing water levels may provide an opportunity for an increase in upland habitat due to disconnection from the river.

Arrowweed

Figure TA 9-11 compares arrowweed suitable habitat under each alternative by Grand Canyon sub-reach. Across all three reaches, all alternatives show similar trends: the generally similar and overlapping interquartile ranges suggest arrowweed would respond in a similar way across all alternatives. The hydrological niche modeling data used to estimate changes to annual total vegetation cover and create **Figure TA 9-11** can be found in Butterfield and Palmquist (2026).

Under the Average Flow Category, across all three sub-reaches, the median for each alternative overlaps or nearly overlaps the modeled historic conditions (dashed line), and the interquartile ranges are relatively small. This indicates that arrowweed suitable habitat may be similar to historic conditions under the Average Flow Category.

Figure TA 9-11
Suitable Modeled Arrowweed (Pluchea sericea) Habitat for each Alternative by Sub-reach



Across all three sub-reaches, under the Wet Flow Category and Moderately Wet Flow Category, the median and interquartile ranges are below the modeled historic conditions (dashed line) for all alternatives except for the interquartile ranges of the No Action Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) in the Moderately Wet Flow Category. This suggests that there would be less arrowweed suitable habitat under the Wet and Moderately Wet Flow Categories under all sub-reaches and all alternatives. Under the Dry Flow Category, the median and interquartile ranges are above historic conditions (dashed line), for all alternatives except the CCS Comparative Baseline and Enhanced Coordination Alternatives. Under the Critically Dry Flow Category, the median and interquartile ranges are above the modeled historic conditions (dashed line) for all sub-reaches and all alternatives except for the CCS Comparative Baseline, although the median remains above historic conditions. This indicates that there may be more arrowweed suitable habitat under the Critically Dry Flow Category for all alternatives across all sub-reaches.

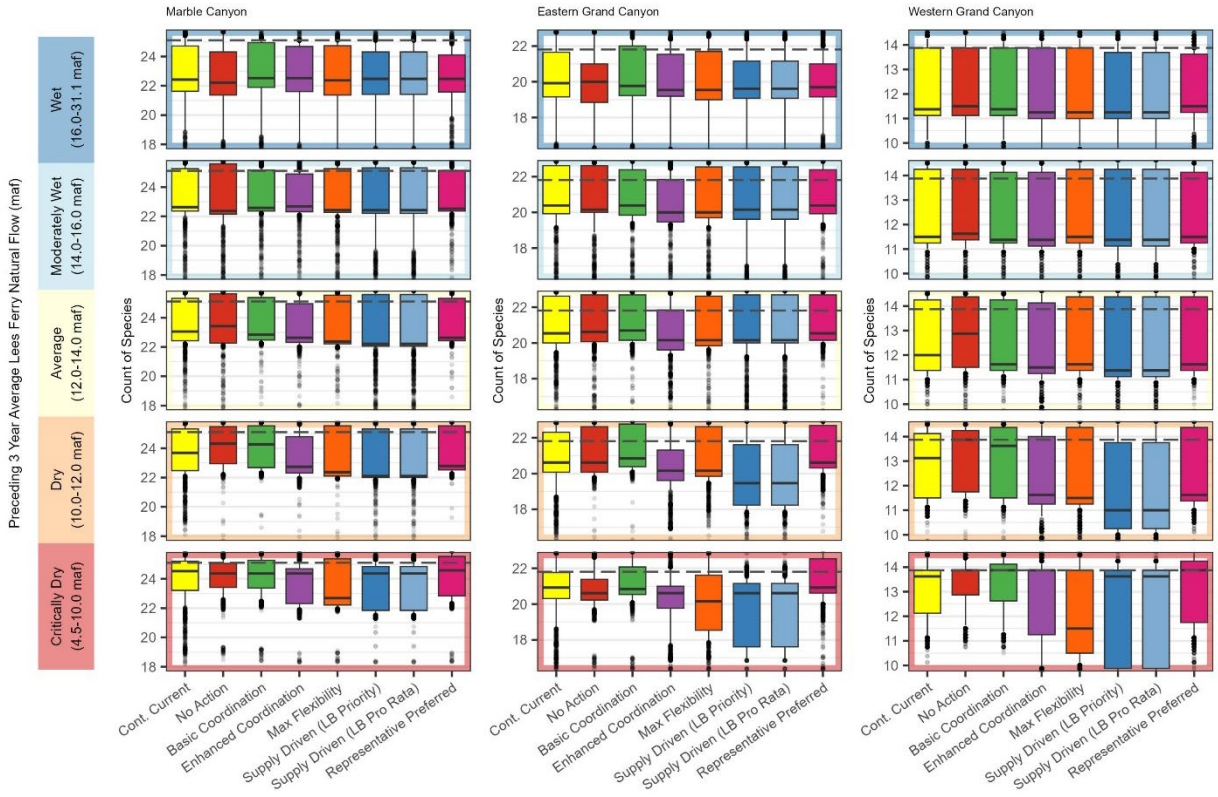
Similar to the discussions under *Marsh* and *Woody Riparian*, the decrease in arrowweed suitable habitat under the Moderately Wet and Wet Flow Categories for all sub-reaches and all alternatives may be because higher water levels reduce the overall available terrestrial habitat (Sankey et al. 2015). HFEs would also have an influence on suitable habitat, with more frequent and longer HFEs impacting vegetation encroachment in various ways depending on geomorphic setting, duration, and flow volume. Conversely, arrowweed suitable habitat may increase under the Dry and Critically Dry Flow Categories, potentially in areas recently exposed by lower water levels. Fewer to no HFEs under the Dry and Critically Dry Flow Categories could also lead to higher vegetation encroachment.

Native Species Richness

Figure TA 9-12 compares the predicted count number of native species (native species richness) under each alternative by Grand Canyon sub-reach. Native species richness includes all habitat types, and does not distinguish between marsh, woody riparian, and upland. Across all three sub-reaches, all alternatives show similar trends: the wide and generally similar interquartile ranges suggest native species richness would respond in a similar way across all alternatives. The hydrological niche modeling data used to estimate changes to native species richness and create **Figure TA 9-12** can be found in Butterfield and Palmquist (2026).

Under all alternatives, sub-reaches, and flow categories, the median is below the modeled historic conditions (dashed line). For some modeled conditions, the interquartile range is above the modeled historic conditions, indicating uncertainty in how vegetation would respond. Since most of the interquartile range is still below the modeled historic conditions, native species richness may decrease under all modeled conditions. However, given the large interquartile ranges, it is difficult to predict how each alternative may respond. Similar to marsh habitat, the Western Grand Canyon reach has larger interquartile ranges than Marble Canyon and Eastern Grand Canyon, indicating greater uncertainty further downstream.

Figure TA 9-12
Native Vegetation Species Richness for each Alternative by Sub-reach



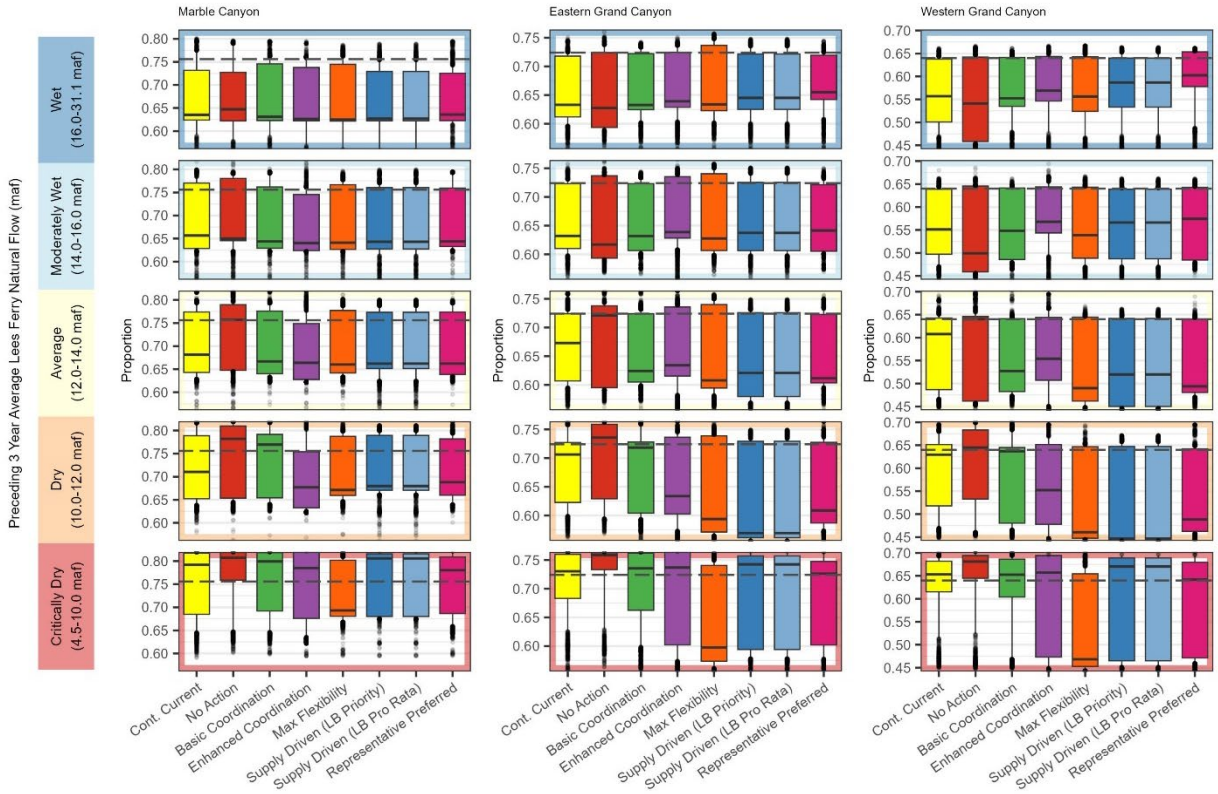
Species richness at the fixed site sandbars declined from 2014-2019, a trend that was driven by low species richness in 2019 (Palmquist et al. 2023). The low species richness in 2019 was likely caused by the HFE that occurred in fall 2018 and the lack of monsoon precipitation in summer 2019. Native species richness may decrease under wet hydrologic conditions as HFEs would be a more frequent occurrence and may decrease under the Critically Dry Flow Category due to a lack of precipitation. Disturbance created by HFEs can also positively impact native species richness, as some species require periodic disturbance. Native species richness may also decrease under the Critically Dry Flow Category due to a lack of HFEs.

Under all conditions, a combination of these hydrological and climatic factors may be driving the variable interquartile ranges.

Proportion Native Species Cover

Figure TA 9-13 compares the proportion of native species cover under each alternative by Grand Canyon sub-reach. Proportion of native species cover includes all habitat types and does not distinguish between marsh, woody riparian, and upland. Across all three sub-reaches, all alternatives show similar trends: the generally wide and similar interquartile ranges in each sub-reach suggest that the proportion of native cover would respond in a similar way across all alternatives. The hydrological niche modeling data used to estimate changes to the proportion of native species cover and create **Figure TA 9-13** can be found in Butterfield and Palmquist (2026).

Figure TA 9-13
Proportion of Native Species Cover for each Alternative by Sub-reach



Similar to native species richness, the proportion of native species cover has large interquartile ranges across all modeled conditions and all alternatives. This indicates a large amount of uncertainty in how vegetation would respond under various conditions.

Within all reaches, under the Wet, Moderately Wet, Average, and Dry Flow Categories modeled conditions, the median is below the modeled historic conditions (dashed line) for all alternatives except for the No Action Alternative and Basic Coordination Alternative under Average and Dry Flow Categories. Since most of the interquartile ranges are below the modeled historic conditions, the proportion of native cover may decrease under Wet, Moderately Wet, Average, and Dry Flow Category conditions under all alternatives and all sub-reaches. However, given the large interquartile ranges, it is difficult to predict how vegetation may respond under each of the modeled conditions, alternatives, and sub-reaches.

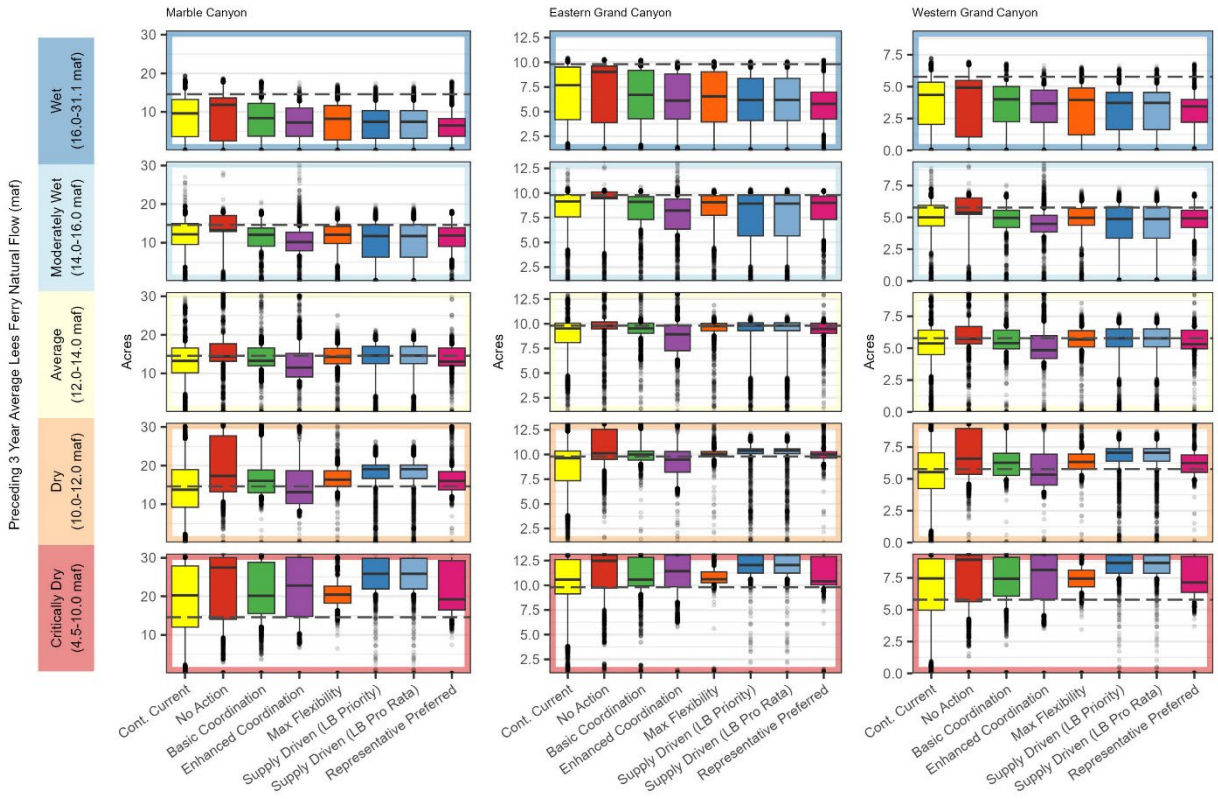
For all sub-reaches, under the Critically Dry Flow Category modeled conditions, the median and interquartile range is above the modeled historic conditions (dashed line) under all alternatives except for the Maximum Operational Flexibility Alternative. This suggests that under the Critically Dry Flow Category modeled conditions, the proportion of native cover may stay similar to historic conditions or increase under most alternatives. However, given the large interquartile ranges, it is difficult to predict how vegetation may respond under each alternative.

Encroachment of riparian vegetation into the exposed active channel and bare sand of sandbars has been found to be driven by seep willows, which are native species (Durning et al. 2021). The proportion of native species cover may decrease under all conditions except for the Critically Dry Flow Category due to a lack of bare sand available for native species, particularly seep willows, to colonize. Seep willows are also less flood tolerant than other species, so the increase in HFE frequency and duration could decrease their suitable area under the Moderately Wet Flow Category. The proportion of native cover may increase under the Critically Dry Flow Category because of receding water levels and subsequent increase in available sand.

Annual Total Vegetation Cover

Figure TA 9-14 compares the annual total vegetation cover under each alternative by Grand Canyon sub-reach. Annual total vegetation cover includes all habitat types and does not distinguish between marsh, woody riparian, and upland. Across all three reaches, all alternatives show similar trends: the generally similar and overlapping interquartile ranges suggest annual total vegetation cover would respond in a similar way across all alternatives. The hydrological niche modeling data used to estimate changes to annual total vegetation cover and create **Figure TA 9-14** can be found in Butterfield and Palmquist (2026).

Figure TA 9-14
Annual Total Vegetation Cover for each Alternative by Sub-reach



Under the Average Flow Category, across all three sub-reaches, the median for each alternative overlaps or nearly overlaps the modeled historic conditions (dashed line), and the interquartile ranges are relatively small. This indicates that annual total vegetation may be similar to historic conditions under the Average Flow Category.

Across all three sub-reaches, under the Wet Flow Category and Moderately Wet Flow Category, the median and interquartile ranges are at or below the modeled historic conditions (dashed line) for all alternatives except for the interquartile range of the No Action Alternative in the Moderately Wet Flow Category, although the median remains below historic conditions. This suggests that there would be less annual total vegetation cover under the Wet and Moderately Wet Flow Categories under all sub-reaches and all alternatives. Under the Dry Flow Category, the medians are above historic conditions (dashed line) for all alternatives except the CCS Comparative Baseline and Enhanced Coordination Alternative. Under the Critically Dry Flow Category, the median and interquartile ranges are above the modeled historic conditions (dashed line) for all sub-reaches and all alternatives except for the CCS Comparative Baseline. This indicates that there may be more annual total vegetation cover under the Dry and Critically Dry Flow Categories.

Similar to the discussions under *Suitable Habitat Area*, the decrease in annual total vegetation cover under the Moderately Wet and Wet Flow Categories for all sub-reaches and all alternatives may be because higher water levels reduce the overall available terrestrial habitat (Sankey et al. 2015). HFEs would also have an influence on annual total vegetation cover; more frequent and longer HFEs would result in lower vegetation encroachment. Conversely, annual total vegetation cover may increase under the Dry and Critically Dry Flow Categories, potentially on areas recently exposed by lower water levels. Fewer to no HFEs under the Dry and Critically Dry Flow Categories could also lead to higher vegetation encroachment.

High Flow Experiments

HFEs influence vegetation dynamics in this reach depending on geomorphic setting, duration, and flow volume. HFEs are dependent on sufficient storage and sediment conditions at Lake Powell. Alternatives that prioritize retaining higher levels in Lake Powell are more likely to result in HFEs, which could influence modeled vegetation responses in this reach. The role of HFEs in shaping vegetation in this reach is described in greater detail in the 2024 LTEMP SEIS (Reclamation 2024).

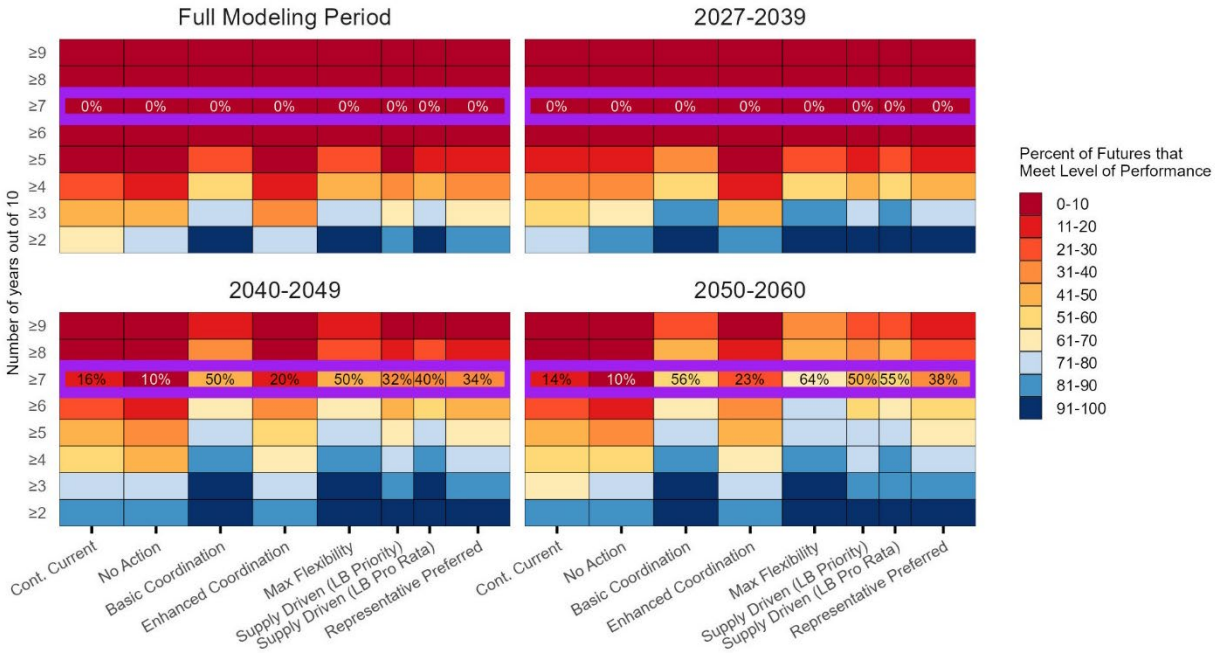
Lake Mead

Marsh Vegetation

The median of the maximum annual change in water surface elevation from WY 2008–2025 was 16.19 feet (**Figure TA 9-15**). Over the past 10 years, WY 2016–2025, the maximum annual change was less than 16.19 feet in 7 of 10 years (**Figure TA 9-15**). These data were used to understand the existing variability in Lake Mead that has led to the current extent of marsh vegetation in the Lake Mead analysis area and are collectively referred to as historic conditions. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, the alternative must have a maximum annual change in water surface elevation of less than 16.19 feet in 7 or more years. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 7 years row is the alternative most similar to historic conditions. **Figure**

TA 9-15 compares the similarity of each alternative to historic maximum annual change in Lake Mead elevation.

Figure TA 9-15
Lake Mead Marsh Riparian Vegetation: Robustness.
Percent of futures in which the maximum annual change in Lake Mead elevation is less than 16.19 feet in the number of years specified by each row during any 10-year period



Note: Supply Driven Lower Basin (LB) Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Similar to Lake Powell, the first decade of modeling for marsh habitat in Lake Mead is influenced by historical data (**Figure TA 9-15**). In the first decade, all alternatives are equally non-robust, meeting the minimum level of performance in 0 percent of futures. For all alternatives, the increased variability from historic conditions in the first decade (2027–2039; **Figure TA 9-15**) of the analysis may result in decreased cover of marsh vegetation.

In later decades (2040–2049 and 2050–2060; **Figure TA 9-15**) when variability becomes closer to historic conditions for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, marsh vegetation may re-establish to a more similar extent compared to the other alternatives. Both of these alternatives are more robust than the CCS Comparative Baseline and No Action Alternative, which meet the minimum level of performance in 16 percent and 14 percent, and 10 percent and 10 percent of futures, respectively. Similar to Lake Powell, when conditions are more variable, cover of nonnative species such as prickly Russian thistle may increase, and if variability decreases, native cover may reestablish.

As shown in **Figure TA 3-11** (see **TA 3**, Hydrologic Resources), the interquartile ranges for all alternatives for the Average Flow Category are above the 2024 WY minimum of 1,061 feet except for the No Action Alternative. The interquartile ranges under the Dry Flow Category are closer to the 2024 WY minimum compared to the Average Flow Category, and the interquartile ranges overlap with the 2024 WY minimum for all alternatives under the Critically Dry Flow Category. This suggests that Lake Mead is likely to lower under drier conditions. Conversely, under the Moderately Wet and Wet Flow Categories, the interquartile ranges shift to be higher than the 2024 WY minimum of 1,061 feet (**Figure TA 3-11**, see **TA 3**, Hydrologic Resources), suggesting that Lake Mead would rise under wetter conditions.

Similar to Lake Powell, whether water elevations rise, fall, or remain the same, if there are similar levels of variability to historic conditions under the Basic Coordination Alternative, Maximum Operational Flexibility Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) in the later decades (**Figure TA 9-15**), marsh vegetation is expected to continue to reestablish along the new water line over time. For alternatives with greater variability than historic conditions (**Figure TA 9-15**), marsh vegetation may re-establish to a smaller extent along the new water line over time. Where variability eliminates or prevents establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type.

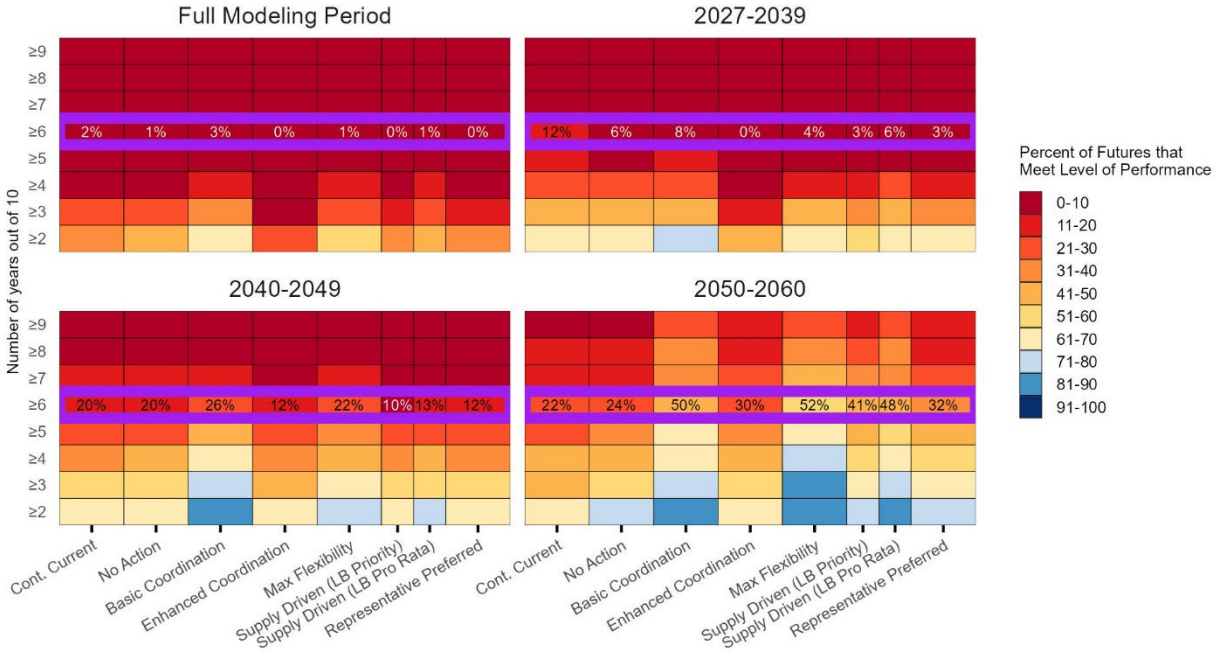
Woody Riparian Vegetation

The median 5-year change in water surface elevation from WY 2008–2025 was 52.24 feet (**Figure TA 9-16**). Over the past 10 years, WY 2016–2025, the 5-year change was less than 52.24 feet in 6 years out of 10 (**Figure TA 9-16**). These data were used to understand the existing variability in Lake Mead that has led to the current extent of woody riparian vegetation in the Lake Mead analysis area and are collectively referred to as historic conditions. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, the alternative must have a maximum 5-year change in water surface elevation of less than 52.24 feet in 6 or more years during every 10-year period. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 6 years row is the alternative most similar to historic conditions. **Figure TA 9-16** compares the similarity of each alternative to the historic maximum 5-year change in Lake Mead elevation.

Similar to Lake Powell, the first decade of modeling for woody riparian vegetation is influenced by historical data (**Figure TA 9-16**). All alternatives meet the minimum level of performance in 12 percent or less of futures.

The later decades (2040–2049 and 2050–2060; **Figure TA 9-16**) begin to trend towards more similar variability compared to historic conditions, but variability still remains high. The Basic Coordination Alternative and the Maximum Operational Flexibility Alternative are more similar to historic conditions, meeting the minimum level of performance in 26 percent and 50 percent and 22 percent and 52 percent of futures, respectively. Both of these alternatives are more robust than the CCS Comparative Baseline and No Action Alternative, which meet the minimum level of performance in 20 percent and 22 percent, and 20 percent and 24 percent of futures, respectively.

Figure TA 9-16
Lake Mead Woody Riparian Vegetation: Robustness.
Percent of futures in which the maximum 5-year change in Lake Mead elevation is less than 52.24 feet in the number of years specified by each row during any 10-year period



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

In later decades (2040–2049 and 2050–2060; **Figure TA 9-16**), when variability becomes more similar to historic conditions for the Basic Coordination Alternative and Maximum Operational Flexibility Alternative, woody riparian vegetation may re-establish to a more similar extent as existing conditions compared to other alternatives. Where variability eliminates or prevents the establishment of woody riparian habitat, upland habitat may become the dominant habitat type.

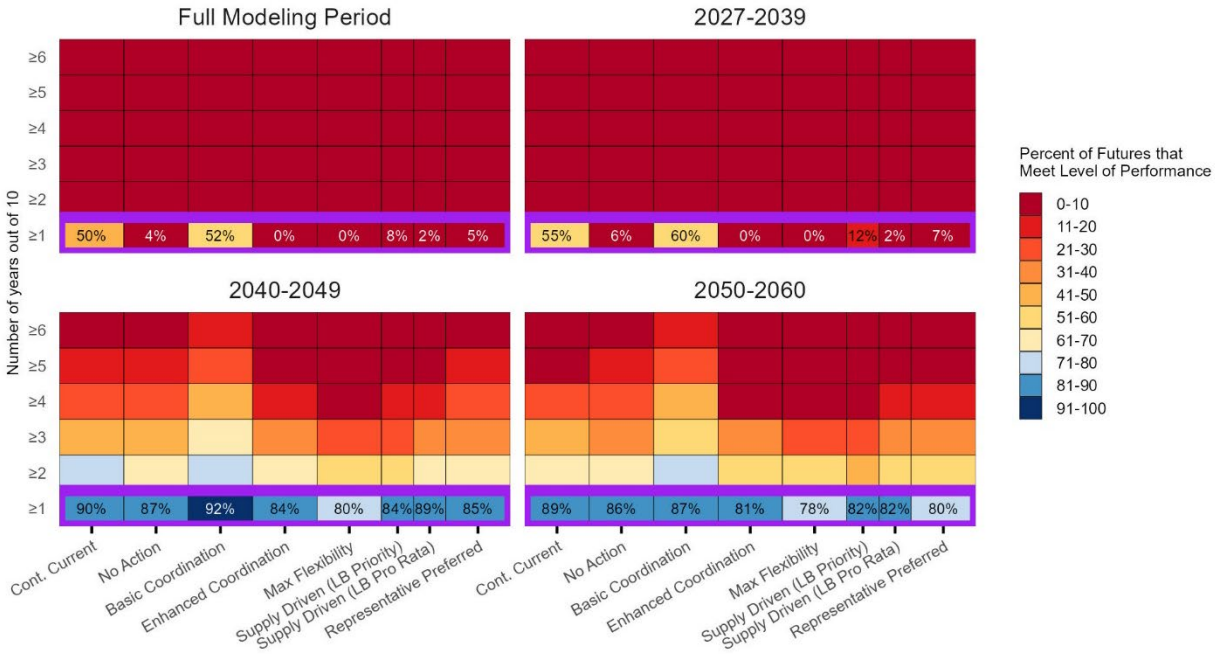
Figure TA 9-15 and **Figure TA 9-16** suggest annual variability in Lake Mead water elevations may be higher, especially in the early decade of the modeling period; however, the variability on a 5-year basis may overall be closer to historic conditions, generally benefiting woody riparian vegetation. As described in **TA 9.1**, historical data indicate that a reduction in variability can create new woody riparian habitat, however, subsequent increases in variability or long term drawdowns can cause vegetation die offs (McKernan and Braden 1998; Reclamation 2004b).

Hoover Dam to SIB

Marsh Vegetation

The median of the maximum annual change in Hoover releases from WY 2008–2025 was 0.256 maf (**Figure TA 9-17**). Over the past 10 years, WY 2016–2025, the maximum annual change was less than 0.256 maf in 1 of 10 years (**Figure TA 9-17**). These data were used to understand the existing variability from Hoover Dam to the SIB, which has led to the current extent of marsh vegetation in the Hoover Dam to the SIB analysis area, and are collectively referred to as historic conditions. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, an alternative must have a change in releases of water of less than 0.256 maf in 1 or more years. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 1 year row is the alternative most similar to historic conditions. **Figure TA 9-17** compares the similarity of each alternative to the historic annual year to year change in Hoover Dam annual release.

Figure TA 9-17
Below Hoover Dam Marsh Riparian Vegetation: Robustness.
Percent of futures in which the year-to-year change in Hoover Dam annual release less than 0.256 maf in the number of years specified by each row during any 10-year period



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Similar to Lake Powell and Lake Mead, the first decade of modeling for marsh vegetation is influenced by historical data (**Figure TA 9-17**). In the first decade, the Basic Coordination Alternative is the most robust, meeting the minimum level of performance in 60 percent of futures. The CCS Comparative Baseline Alternative and No Action Alternative meet it in 55 percent and 6 percent of futures, respectively. For all alternatives, the increased variability from historic conditions in the first decade (2027–2039; **Figure TA 9-17**) may result in decreased marsh vegetation cover.

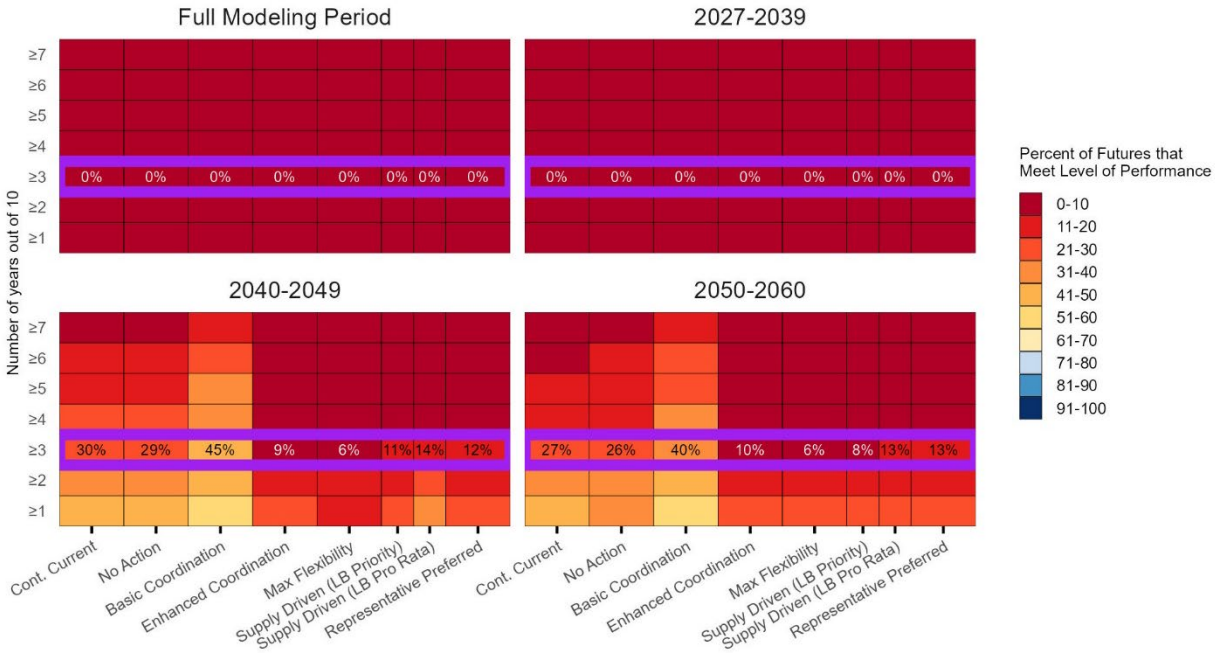
In later decades (2040–2049 and 2050–2060; **Figure TA 9-17**), all alternatives trend towards more similar variability compared to historic conditions. All alternatives meet the minimum level of performance in 78 percent or more of futures. As variability becomes closer to historic conditions, marsh vegetation may re-establish to a similar extent. Where variability eliminates or prevents the establishment of marsh habitat, woody riparian or upland habitat may become the dominant habitat type.

During the 2007 Interim Guidelines period, the annual volume of the Colorado River below Hoover averaged 9.185 maf (see **Section TA 3.1**, Affected Environment, in **TA 3**, Hydrologic Resources). For all alternatives under Average and Dry Flow Categories, the interquartile ranges of the modeled annual volume are below 9.185 maf (**Table TA 3-21** and **Figure TA 3-27**, in **TA 3**, Hydrologic Resources). This suggests that the annual flow volume below Hoover Dam may decrease under all alternatives in Average and Dry Flow Categories. The 2007 Interim Guidelines reduced average annual releases from Hoover Dam by approximately 1.014 maf from prior operating guidelines (see **Section TA 3.1**, Affected Environment, in **TA 3**, Hydrologic Resources). As described in **TA 9.1**, recent change analysis indicates marsh vegetation has generally decreased from 2000 to 2024 (RiverRestoration.Org 2025). If water releases decrease with higher levels of variability compared to historic conditions (**Figure TA 9-17**), marsh vegetation is expected to continue to decrease over time under Average and Dry Flow Categories. If water releases decrease with similar levels of variability to historic conditions (**Figure TA 9-17**), marsh vegetation is expected to decline at a rate similar to existing conditions under Dry and Critically Dry Flow Categories.

Woody Riparian

The median of the maximum 5-year change in Hoover releases from WY 2008–2025 was 0.338 maf (**Figure TA 9-18**). Over the past 10 years (WY 2016–2025), maximum annual change was less than 0.338 maf feet in 3 of 10 years (**Figure TA 9-18**). These data were used to understand the existing variability in flows from Hoover Dam to the SIB that has led to the current extent of marsh vegetation in the Hoover Dam to the SIB analysis area and are collectively referred to as historic conditions. The minimum level of performance was established based on these historic conditions. Therefore, to meet the minimum level of performance, an alternative must have a change in the 5-year average release of water of less than 0.338 maf in 3 or more years. The more times an alternative meets that criterion, the higher the percentage in each respective box. The alternative with the highest percentage within the greater than or equal to 3 years row is the alternative most similar to historic conditions. **Figure TA 9-18** compares the similarity of each alternative to the historic 5-year average year to year change in Hoover Dam annual release.

Figure TA 9-18
Below Hoover Dam Woody Riparian Vegetation: Robustness.
Percent of futures in which the 5-year average year-to-year change in Hoover Dam annual release is less than 0.338 maf in the number of years specified by each row during any 10-year period



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Similar to Lake Powell and Lake Mead, the first decade of modeling for woody riparian vegetation is influenced by historical data (**Figure TA 9-18**). In the first decade, all alternatives are equally non-robust, meeting the minimum level of performance in 0 percent of futures. Increased variability from historic conditions in the first decade (2027–2039; **Figure TA 9-18**) may result in decreased woody riparian vegetation cover due to inconsistent water availability.

In later decades (2040–2049 and 2050–2060; **Figure TA 9-18**) all alternatives trend towards variability more similar to historic conditions, but variability still remains high. The Basic Coordination Alternative is the most robust, meeting the minimum level of performance in 45 percent and 40 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative meet it in 30 percent and 27 percent, and 29 percent and 26 percent of futures, respectively. This increased variability may result in decreased riparian vegetation cover for all alternatives, but to a lesser extent under the Basic Coordination Alternative and No Action Alternative. Where variability eliminates or prevents woody riparian habitat establishment, upland habitat may become the dominant habitat type.

Previous planning efforts, including the LCR MSCP HCP, 2007 Final EIS, 2024 LTEMP SEIS, and their associated Biological Assessments (Reclamation 2004a, 2004c, 2016, 2022, 2023, 2024) assessed and predicted the quantities of habitat impacts from ongoing and future reductions in flow from Hoover Dam, which are here incorporated by reference. The best available information at this time indicates that these analyses are still valid based on predicted operations of Hoover Dam and the dams and diversions between Hoover Dam and SIB. A summary of FWS consultation for this planning effort is included in **Chapter 4**, Consultation and Coordination.

Federal, state, and tribal managed areas, such as Cibola National Wildlife Refuge, depend on water from the Colorado River to ensure woody riparian and marsh habitat. If water in the river drops below the level at which water is able to properly flow through diversion structures or pumps are able to function, there may be impacts on these habitats unless another method is used to transport water to the managed habitat areas. If a prolonged period of dryness occurs, woody riparian and marsh vegetation may begin to desiccate; however, the extent to which this would occur is unknown.

TA 9.2.3 Summary Comparison of Alternatives

Marsh vegetation requires consistent inundation, so when variability increases from historic conditions on an annual scale, marsh vegetation extent is expected to decrease. Woody riparian vegetation is more resilient to water fluctuations, but when variability increases from historic conditions on a 5-year scale, woody riparian vegetation extent is expected to decrease. Similarly, if variability decreases on an annual or 5-year scale, marsh, woody riparian, or upland vegetation may increase in extent.

For Lake Powell marsh and woody riparian vegetation, the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative would result in vegetation most similar to historic conditions (**Table TA 9-4**). The Maximum Operational Flexibility Alternative would also result in vegetation most similar to historic conditions for Lake Mead marsh and woody riparian vegetation. However, for Hoover Dam to the SIB reach, the Maximum Operational Flexibility Alternative and Enhanced Coordination Alternative would result in vegetation least similar to historic conditions, which would result in larger changes in vegetation compared to historic conditions for that reach. Similarly, the Basic Coordination Alternative would result in conditions least similar to historic conditions for Lake Powell woody riparian vegetation, but would be closest to historic conditions for Lake Mead and Hoover Dam to the SIB. This suggests that no single alternative would result in vegetation similar to historic conditions across all reaches. For all reaches, multiple alternatives provide variability more similar to historic conditions than the CCS Comparative Baseline, except for the Hoover Dam to SIB reach, where all alternatives are similarly robust for marsh vegetation. This suggests that a change in management from the current strategies would benefit a large portion of the analysis area.

Table TA 9-4
The Alternatives that Result in the Most Similar or Least Similar Conditions compared to Historic Conditions for All Reaches and Vegetation Types

Reach and Vegetation Type	Most Similar to Historic Conditions	Least Similar to Historic Conditions
Lake Powell Marsh	Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative	Supply Driven Alternative (both LB Priority and LB Pro Rata approaches)
Lake Powell Woody Riparian	Enhanced Coordination Alternative, Maximum Operational Flexibility Alternative	Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Representative Preferred Alternative, Basic Coordination Alternative
Glen Canyon Dam to Lake Mead Marsh	Variable based on hydrology	Variable based on hydrology
Glen Canyon Dam to Lake Mead Woody Riparian	Variable based on hydrology	Variable based on hydrology
Lake Mead Marsh	Maximum Operational Flexibility Alternative, Basic Coordination Alternative	No Action Alternative, CCS Comparative Baseline
Lake Mead Woody Riparian	Basic Coordination Alternative, Maximum Operational Flexibility Alternative	No Action Alternative, CCS Comparative Baseline, Enhanced Coordination Alternative, Representative Preferred Alternative
Hoover Dam to SIB Marsh	All Alternatives Similarly Robust	All Alternatives Similarly Robust
Hoover Dam to SIB Woody Riparian	Basic Coordination Alternative	Maximum Operational Flexibility Alternative, Enhanced Coordination Alternative, Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Representative Preferred Alternative

For the Glen Canyon Dam to Lake Mead reach, the alternative that would result in vegetation patterns most similar to historic conditions depends strongly on the flow categories. Under the Dry and Critically Dry Flow Categories, some differences among the alternatives emerge, presumably because there are greater differences in the lowest flows, the median flows, and peak flows under those conditions. However, across all alternatives, all sub-reaches, and all evaluated criteria (suitable habitat area, arrowweed, native species richness, proportion native species cover, and annual total vegetation cover), the interquartile ranges often overlap. When the interquartile ranges overlap, it is difficult to determine whether one alternative is truly different from another. Therefore, no single alternative emerged as the best or worst for retaining vegetation similar to historic conditions. The Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative prioritize protecting elevations in Lake Powell and are therefore most likely to result in HFEs in this reach.

For all alternatives in Lake Powell, Lake Mead, and Hoover Dam to the SIB, the first decade would experience more variability, which would result in a reduction in marsh, woody riparian, and upland habitat compared to historic conditions. All alternatives see conditions return closer to historic conditions in the second and third decades, which may result in vegetation reestablishing to a similar extent. Where variability eliminates or prevents the establishment of marsh, woody riparian, or upland habitat, there may be a shift to one of the other habitat types.

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TA 9 Attachment 1

Special Status Plant Species Table

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TA 9 Attachment 1. Special Status Plant Species

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Alkali mariposa lily *(Calochortus striatus)*	BLM NV	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025a).
Amargosa buckwheat *(Eriogonum contiguum)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025a).
Amargosa niterwort *(Nitrophila mohavensis)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (CDFW 2013).
Antelope Canyon goldenbush *(Ericameria cervina)*	BLM NV	Upland	—	—	—	—	No, this species has been observed upland areas which would not be affected by any alternatives (NatureServe 2025b).
Aravaipa sage *(Salvia amissa)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Botanical Realm 2024).
Aravaipa woodfern *(Thelypteris puberula var. sonorensis)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025c).
Arizona chalk dudleya *(Dudleya pulverulenta ssp. arizonica)*	BLM NV	Upland	—	X	—	—	Yes, this species has been observed in the analysis area and could be affected by inundation (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025, FNA 2020).

BLM = Bureau of Land Management; CA = California; NV = Nevada; NPS = National Park Service; LCR MSCP = Lower Colorado River Multi-Species Conservation Program; AZ = Arizona.

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Arizona claret cup (*Echinocereus canyonensis*)	N/A	Upland	—	X	—	—	Yes, this species has been observed in the analysis area and could be affected by inundation (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Arizona eryngo *(Eryngium sparganophyllum)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (FWS 2025a).
Arizona Sonora rosewood *(Vauquelinia californica ssp. sonorensis)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Arizona Rare Plant Committee n.d.).
Arizona centaury (*Zeltnera arizonica*)	N/A	Marsh	—	X	—	—	Yes, the species has been documented in the analysis area (Palmquist et al. 2023).
Ash Meadows blazingstar *(Mentzelia leucophylla)*	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025b).
Ash Meadows gumplant *(Grindelia fraxinipratensis)*	BLM NV	Marsh, Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025d).
Ash Meadows ladies tresses *(Spiranthes diluvialis)*	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025e).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Ash Meadows milkvetch *(Astragalus phoenix)*	BLM NV, Threatened	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025f).
Ash Meadows mousetails *(Ivesia kingii* var. *eremica)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025c).
Ash Meadows sunray *(Enceliopsis nudicaulis* var. *corrugata)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025g).
Bartram stonecrop *(Graptopetalum bartramii)*	BLM AZ	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025d).
Bearded screwmoss *(Pseudocrossidium crinitum)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025h).
Beatley's milkvetch *(Astragalus beatleyae)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NNSS 2024a).
Beatley's scorpionflower *(Phacelia beatleyae)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NNSS 2024b).
Beaver dam breadroot *(Pediomelum castoreum)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025i).
Black woollypod *(Astragalus funereus)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025j).

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Blue diamond cholla *(Cylindropuntia multigeniculata)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (Baker 2005).
Blue sand lily *(Triteleiopsis palmeri)*	BLM AZ	Upland	—	—	—	X (7)	No, this species grows on sand dunes, which would not be affected by any alternative (NatureServe 2025k).
Bullfrog Hills sweetpea *(Lathyrus hitchcockianus)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025l).
Calico Basin sunflower *(Helianthus devernii)*	BLM NV	Upland	—	—	—	—	No, this species is only found at Red Rock Canyon National Conservation Area (NatureServe 2025m).
California flannelbush *(Fremontodendron californicum)*	BLM AZ	Upland	—	—	—	—	No, the analysis area is outside the range of this species (Abrahamson 2021).
California screw moss *(Tortula californica)*	BLM CA	Upland	—	—	—	—	No, the analysis area is outside the range of this species (Calflora 2025a).
California sawgrass (*Cladium californicum*)	N/A	Marsh	—	X	—	—	Yes, the species has been documented in the analysis area (Palmquist et al. 2023).
Cane Spring suncup *(Chylismia megalantha)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (FNA 2022).
Chaparral sand-verbena *(Abronia villosa var. aurita)*	BLM CA	Upland	—	—	—	—	No, the analysis area is outside the range of this species (UC Berkeley 2025a).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Charleston grounddaisy *(Townsendia jonesii var. tumulosa)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (GBIF 2023).
Charleston Mountain angelica *(Angelica scabrida)*	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025n).
Charleston violet *(Viola charlestonensis)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025o).
Clarke phacelia *(Phacelia filiae)*	BLM NV	Upland	—	—	—	—	No, this species is endemic to a small area in southern Nevada, outside the analysis area (NNSS 2024c).
Clark Mountain agave *(Agave utahensis var. nevadensis)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025p).
Clark Mountain green gentian *(Frasera albomarginata var. induta)*	BLM NV	Upland	—	X	—	—	No, this species is limited to Clark Mountains in Nevada (FNA 2025a).
Clokey buckwheat *(Eriogonum heermannii var. clokeyi)*	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025q).
Clokey Mountain sage *(Salvia dorrii var. clokeyi)*	BLM NV		—	—	—	—	No, this species is found in the Spring Mountains west of Las Vegas and the analysis area is not within its range (NatureServe 2025r).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Cochise sedge *(Carex ultra)*	BLM AZ	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025s).
Coulter's goldfields *(Lasthenia glabrata ssp. coulteri)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025t).
Dainty moonwort *(Botrychium crenulatum)*	BLM NV	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025u).
Deane's milkvetch *(Astragalus deanei)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (UC Berkeley 2025b).
Death Valley beardtongue *(Penstemon fruticiformis ssp. amargosae)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (iNaturalist 2025a).
Death Valley sage *(Salvia funerea)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside the areas affected by any alternatives (CNPS 2025b).
Decumbent goldenbush *(Isocoma menziesii var. decumbens)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025v).
Delicate clarkia *(Clarkia delicata)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025w).
Desert mountain thistle *(Cirsium arizonicum)*	BLM NV	Upland	—	X	—	—	Yes, this species has been observed in the analysis area and could be affected by inundation (iNaturalist 2025b).

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Dune spurge *(Euphorbia platysperma)*	BLM CA	Upland	—	—	—	X (7)	No, this species occurs in upland desert dune and scrub habitats which would not be affected by any alternative (Arizona Rare Plant Committee n.d.).
Dune sunflower *(Helianthus deserticola)*	BLM NV	Upland	X	—	X	—	Yes, this species has been observed in the analysis area and could be affected by inundation (iNaturalist 2025c).
Dunn's mariposa lily *(Calochortus dunnii)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025c).
Eastern joshua tree *(Yucca jaegeriana)*	BLM NV	Upland	—	—	X	X (2)	Yes, species has been documented within analysis area (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Entire leaved thelypody (*Thelypodium integrifolium*)	N/A	Upland	—	X	—	—	Yes, species has been documented within analysis area (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Fish Creek fleabane *(Erigeron piscaticus)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025x).
Felt-leaved monardella *(Monardella hypoleuca ssp. lanata)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025d).
Gander's pitcher sage *(Lepechinia ganderi)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025e).

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Gander's ragwort *(Packera ganderi)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025y).
Garret's California fuchsia *(Epilobium canum ssp. garrettii)*	BLM NV	Woody Riparian	—	—	—	—	No, this species has not been observed in the analysis area (iNaturalist 2025d).
Gilman's milkvetch *(Astragalus gilmanii)*	BLM NV	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025z).
Gold butte moss *(Didymodon nevadensis)*	BLM NV	Woody Riparian	—	?	X	—	Yes, this species is found in Gold Butte north of Lake Mead, Arizona and Utah. This species may be present in other locations with gypsum soils (Zander et al. 1995).
Golden crispleaf buckwheat *(Eriogonum corymbosum var. aureum)*	BLM NV	Upland	—	X	—	—	No, this species is present in creosote bush and blackbrush communities which are above analysis area (SEINet 2025a).
Goodding's willow (*Salix gooddingii*)	N/A	Woody Riparian	X	X	X	X	Yes, the species has been documented in the analysis area (Palmquist et al. 2023).
Grand Canyon rose *(Rosa stellata var. abyssa)*	BLM AZ	Upland	—	X	—	—	No, this species grows in upland habitat which would not be affected by any alternative (NatureServe 2025aa).
Gypsum Cave evening primrose *(Oenothera cavernae)*	BLM NV	Woody Riparian	—	X	—	—	Yes, this species is common in Grand Canyon National Park and in canyon washes (NatureServe 2025bb).

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Half-ring milkvetch *(Astragalus mohavensis var hemigyrus)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025f).
Harrison's barberry *(Berberis harrisoniana)*	BLM AZ	Upland	—	X	—	—	No, this species grows on talus slopes on and along canyon sides, which would not be affected by any alternative (NatureServe 2025cc).
Harwood's eriastrum *(Eriastrum harwoodii)*	BLM CA	Upland	—	—	—	X (6)	No, this species grows in upland habitat near the Rosevelt Mine, which would not be affected by any alternative (CNPS 2025g).
Newberry's mock yucca (*Hesperoyucca newberryi*)	N/A	Upland	—	X	—	—	No, this species grows on rocky granite slopes in upland habitats, which would not be affected by any alternative (SEINet 2025b).
Hohokam agave *(Agave murpheyi)*	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025dd).
Horn's milk- vetch *(Astragalus hornii var. hornii)*	BLM CA	Marsh	—	—	—	—	No. This species' range is outside of areas affected by any alternatives. (CNPS 2025h)
Huachuca golden aster *(Heterotheca rutteri)*	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ee).
Hualapai blazingstar (*Mentzelia hualapaiensis*)	N/A	Woody Riparian	—	X	X	—	Yes, species can occur in upland and woody riparian habitats (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).

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Ivory-spined agave *(Agave utahensis var. eborispina)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (iNaturalist 2025e).
Jaeger beardtongue *(Penstemon thompsoniae ssp. jaegeri)*	BLM NV	Upland	—	—	—	—	No, this species has not been observed in the analysis area (iNaturalist 2025f).
Jaeger's ivesia *(Ivesia jaegeri)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ff).
Johnson's Fishhook Cactus *(Echinomastus johnsonii)*	NPL	Upland			X	X (2)	Yes, this species could be affected by inundation (NatureServe 2025gg).
Kaibab agave (*Agave utahensis ssp. kaibabensis*)	N/A	Upland	—	X	—	—	No, this species grows on rocky outcrops in upland habitats, which would not be affected by any alternative (SEINet 2025c).
Lace-leaved rockdaisy *(Perityle ambrosiifolia)*	BLM AZ	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025hh).
Lakeside ceanothus *(Ceanothus cyaneus)*	BLM CA	Upland	—	—	—	—	No, this species grows in upland habitats, which would not be affected by any alternative (NatureServe 2025ii).
Las Vegas bearpoppy *(Arctomecon californica)*	BLM NV	Marsh	—	—	X	—	Yes, this species is found around Lake Mead in gypsum soils (NatureServe 2025jj).

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Las Vegas buckwheat *(Eriogonum corymbosum var. nilesii)*	BLM NV	Upland	—	—	—	—	No, this species grows in upland gypsum soils, which would not be affected by any alternative (NatureServe 2025kk).
Las Vegas catseye *(Oreocarya insolita)*	BLM NV	Upland	—	—	—	—	No, it is suggested this species is currently extinct (NPS 2010).
Latimer's woodland-gilia *(Saltugilia latimeri)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025d).
Limestone monkeyflower *(Erythranthe calcicola)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025e).
Lincoln rockcress *(Boechera lincolnensis)*	BLM CA	Upland	—	—	—	—	No, this species grows in upland habitat, which would not be affected by any alternative (SEINet 2025f).
Littlefield milkvetch *(Astragalus preussii var. laxiflorus)*	BLM NV	Upland	—	—	X	—	Yes, this species has been observed near Lake Mead (SEINet 2025g).
Little San Bernardino Mtns. linanthus *(Linanthus maculatus ssp. maculatus)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025i).
Long-spined spineflower *(Chorizanthe polygonoides var. longispina)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025h).

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Longstem evening primrose (*Oenothera longissima ssp. typica*)	N/A	Woody Riparian	—	X	—	—	Yes, species has been documented along Colorado River in Grand Canyon (SEINet 2025i).
Maguire's lewisia *(Lewisia maguirei)*	BLM NV	Upland	—	—	—	—	No, this species is associated with pinyon-juniper woodlands which would not be affected by any alternatives (NatureServe 2025ll).
Marble Canyon milkvetch *(Astragalus cremnophylax var. hevronii)*	BLM AZ	Upland	—	X	—	—	No, this species grows along canyon edges, which would not be affected by any alternative (Arizona Rare Plant Committee n.d.).
Meadow Valley sandwort *(Eremogone stenomeres)*	BLM NV	Upland	—	—	—	—	No, there are no known populations of this species within the areas affected by any alternatives (SEINet 2025j).
Mecca-aster *(Xylorhiza cognata)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025mm).
McDougall's flaveria (*Flaveria mcdougallii*)	N/A	Marsh	—	X	—	—	Yes, this species is found in Grand Canyon and occurs in alkaline seeps and springs (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Mojave fishhook cactus *(Sclerocactus polyancistrus)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025nn).

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Mojave indigo bush *(Psorothamnus arborescens var. pubescens)*	BLM AZ	Upland	—	X	—	—	Yes, this species is found in Grand Canyon and can occur in washes (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Mojave monarrdella *(Monardella mojavensis)*	BLM NV	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025j).
Mojave tarplant *(Deinandra mohavensis)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025k).
Mojave thistle *(Cirsium mohavense)*	BLM NV	Woody Riparian	—	X	—	—	Yes, this species is found in Grand Canyon and occurs in hanging gardens and wet soil in canyons (NatureServe 2025oo). *C. mohavense* populations in Grand Canyon may be a *Cirsium* species new to science (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Mokiak milkvetch *(Astragalus mokiacensis)*	BLM NV	Upland	—	—	X	—	Yes, this species has been observed within the full pool line of Lake Mead and could be affected by inundation (SEINet 2025l).
Mount Trumbull beardtongue *(Penstemon distans)*	BLM AZ	Upland	—	X	—	—	No, this species grows in upland forest and woodland habitat, which would not be affected by any alternative (NatureServe 2025pp).
Mourning buckwheat *(Eriogonum concinnum)*	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of the species (SEINet 2025m).

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Nakestem sunray (*Enceliopsis nudicaulis*)	N/A	Woody Riparian	—	X	X	—	Yes, this species has been documented within full pool of Lake Mead (SEINet 2025n)
Nevada willowherb *(Epilobium nevadense)*	BLM NV	Woody Riparian	—	X	—	—	Yes, this species is found in Grand Canyon and grows on gravelly slopes, canyon walls, and sandy soils (NatureServe 2025qq).
Nuttall's scrub oak *(Quercus dumosa)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Caliscape 2025).
Nye milkvetch *(Astragalus nyensis)*	BLM NV	Woody Riparian	—	—	X	—	Yes, Lake Mead is within the range of this species (Nature Serve 2025rr).
Oil neststraw *(Stylocline citroleum)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025k).
Orcutt's brodiaea *(Brodiaea orcuttii)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025o).
Orocopia Mountains spurge *(Euphorbia jaegeri)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ss).
Otay manzanita *(Arctostaphylos otayensis)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025tt).
Otay Mountain ceanothus *(Ceanothus otayensis)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025p).
Pahrump silverscale *(Atriplex argentea var. longitrichoma)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025uu).

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Pahrump Valley buckwheat *(Eriogonum bifurcatum)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025vv).
Pahute Mesa beardtongue *(Penstemon pahutensis)*	BLM NM	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ww).
Panamint Spring beauty *(Claytonia panamintensis)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (CNPS 2025l).
Parish's meadowfern *(Limnanthes alba ssp. parishii)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025xx).
Parish Onion *(Allium parishii)*	BLM AZ	Upland	—	—	—	X (3 [full pool Lake Havasu])	Yes, this species has been observed in the analysis area (SEINet 2025q).
Parish's phacelia *(Phacelia parryi)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025r).
Parry's spineflower *(Chorizanthe parryi var. parryi)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025yy).
Parry's tetracoccus *(Tetracoccus dioicus)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025zz).

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Peach Springs cholla (*Cylindropuntia abyssi*)	N/A	Upland	—	X	X	—	Yes, species has been documented within analysis area (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Peirson's milk-vetch *(Astragalus magdalenae var. peirsonii)*	BLM CA, Threatened	Upland	—	—	—	—	No, this species occurs in aeolian dunes between the Salton Sea and Colorado River, outside of areas affected by any alternatives (FWS 2022).
Pima Indian mallow *(Abutilon parishii)*	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Arizona Rare Plant Committee n.d.).
Pintwater rabbitbrush *(Chrysothamnus eremobius)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025aaa).
Planoconvex cordmoss *(Entosthodon planoconvexus)*	BLM NV	Woody Riparian	—	—	—	—	Yes, this species prefers desert washes and canyons which occur in the analysis area (NatureServe 2025bbb).
Polished blazing star *(Mentzelia polita)*	BLM NV	Upland	—	—	—	—	No, this species is restricted to gypsum or mixed gypsum and clay soils in Mohave County at elevations between 1350-1500m (SEINet 2025s).
Rainbow manzanita *(Arctostaphylos rainbowensis)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Calflora 2025b).
Ramona horkelia *(Horkelia truncata)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025t).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Red Rock Canyon false golden aster *(Ionactis caelestis)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (Nesom and Leary 1992).
Reese River phacelia *(Phacelia glaberrima)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ccc).
Reveal's buckwheat *(Eriogonum contiguum)*	BLM CA	Woody Riparian	—	—	—	X (2 and 3)	Yes, this species is associated with lower bajadas in California and southern Clark County Nevada (NatureServe 2025ddd).
Robinson's monardella *(Monardella robinsonii)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025eee).
Rock purpusia *(Ivesia arizonica var. saxosa)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025fff).
Rosy twotone beardtongue *(Penstemon bicolor ssp. roseus)*	BLM NV, BLM AZ	Woody Riparian	—	—	X	X (2)	Yes, this species may be found within full pool of Lake Mead (NPS 2004)
Rough dwarf greasebush *(Glossopetalon pungens var. pungens)*	BLM NV	Upland	—	—	—	—	No, there are no known occurrences of this species in the analysis area (iNaturalist 2025g).
Rough fringemoss *(Crossidium seriatum)*	BLM NV	Woody Riparian	—	—	X	—	Yes, this species has been observed in the analysis area (COSEWIC 2014).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Rush lemonweed (*Psoralidium junceum*)	N/A	Woody Riparian	—	X	—	—	Yes, this species is found in Grand Canyon and can occur in washes (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
St. George blue-eyed grass *(Sisyrinchium radicatum)*	BLM NV	Woody Riparian	—	—	X	—	Yes, this species can occupy riparian areas and has been observed in the analysis area (NatureServe 2025ggg).
Salt marsh bird's-beak *(Chloropyron maritimum ssp. maritimum)*	BLM CA	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025hhh).
San Bernadino milk-vetch *(Astragalus bernardinus)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025u).
San Diego goldenstar *(Bloomeria clevelandii)*	BLM CA	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025iii).
San Diego gumplant *(Grindelia hallii)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025v).
San Diego milk- vetch *(Astragalus oocarpus)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025jjj).
Sandfood *(Pholisma sonorae)*	BLM AZ	Upland	—	—	—	X (7)	No, this species is endemic to sand dunes and would not likely be found in washes (SEINet 2025w).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Sanicle biscuitroot *(Cymopterus ripleyi var. saniculoides)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025kkk).
San Jacinto mariposa-lily *(Calochortus palmeri var. munzii)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025x).
San Luis Obispo sedge *(Carex obispoensis)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025lll).
San Miguel savory *(Clinopodium chandleri)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025mmm).
Sanford's arrowhead *(Sagittaria sanfordii)*	BLM CA	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025nnn).
Santa Lucia dwarf rush *(Juncus luciensis)*	BLM CA	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025ooo).
Satin-tail (*Imperata brevifolia*)	N/A	Marsh	—	X	—	—	Yes, the species has been documented in the analysis area (Palmquist et al. 2023).
Scaly sandplant *(Pholisma arenarium)*	BLM AZ	Upland	—	X	X	X (4)	No, this species grows in upland sand and dune habitats, which would not be affected by any alternative (NatureServe 2025ppp).
Screwbean mesquite *(Prosopis pubescens)*	BLM NV	Woody Riparian	—	—	X	X (2, 3, 4, 5, 6, 7)	Yes, this species is present in riparian areas with honey mesquite and cottonwood-willow and has been observed near the Little Colorado River (Meyer 2005).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Scrub lotus *(Lotus argyraeus var. multicaulis)*	BLM NV	Upland	—	—	—	—	No, this species is endemic to desert mountains which would not be affected by any alternatives (NatureServe 2025qqq).
Sheep fleabane *(Erigeron ovinus)*	BLM NV	Upland	—	—	—	—	No, this species is endemic to the Sheep and Groom ranges and on Mt. Irish in Nevada (NatureServe 2025rrr).
Sheep Range milkvetch *(Astragalus amphioxys var. musimonum)*	BLM NV	Upland	—	—	—	—	No, this species variety has not been observed in the analysis area (SEINet 2025y).
Shevock's copper moss *(Mielichhoferia shevockii)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025sss).
Siler fishhook cactus *(Sclerocactus sileri)*	BLM AZ	Upland	—	X	—	—	No, this species grows in upland desert habitats which would not be affected by any alternatives (NatureServe 2025ttt).
Silverleaf sunray *(Enceliopsis argophylla)*	BLM AZ, BLM NV	Upland	—		X	X (2)	Yes, this species can occupy riparian areas and has been observed near the analysis area (SEINet 2025z).
Small wirelettuce *(Stephanomeria exigua ssp. exigua)*	BLM AZ	Upland	—	—	—	—	No, this species has not been documented in areas affected by alternatives (SEINet 2025aa).
Smooth dwarf greasebush *(Glossopetalon pungens var. glabrum)*	BLM NV	Upland	—	—	—	—	No, this species prefers mountain ranges which would not be affected by any alternatives (FNA 2025b).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Snake cholla *(Cylindropuntia californica var. californica)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025bb).
Southwestern ringstem *(Anulocaulis leisolenus var. leisolenus)*	BLM NV	Woody Riparian	—	X	—	—	Yes, species has been collected near Colorado River (personal communication, Wendy Hodgson, Desert Botanical Garden, to Lonnie Pilkington, NPS, October 28, 2025).
Spring-loving century plant *(Zeltnera namophila)*	BLM NV	Marsh	—	—	—	—	No, this species is endemic to Nye County Nevada in Ash Meadows (SEINet 2025cc).
Spring Mountains milkvetch *(Astragalus remotus)*	BLM NV	Upland	—	—	—	—	No, this species grows in upland talus and rocky slopes which would not be affected by any alternative (NatureServe 2025uuu).
Sticky buckwheat *(Eriogonum viscidulum)*	BLM AZ, BLM NV, LCR MSCP	Upland	—	—	X	—	Yes, this species can occupy riparian areas and has been observed near the analysis area (SEINet 2025dd).
Sticky dudleya *(Dudleya viscida)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (SEINet 2025ee).
Sticky ringstem *(Anulocaulis leiosolenus)*	BLM NV	Upland	—	—	X	—	No, this species grows in upland habitats which would not be affected by any alternative (Rees 2007).
Straw milkvetch *(Astragalus lentiginosus var. stramineus)*	BLM NV	Upland	—	—	X	—	Yes, this species has been observed within the analysis area (iNaturalist 2025h).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Summer holly *(Comarostaphylis diversifolia ssp. Diversifolia)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025vvv).
Sweet moustache moss *(Trichostomum sweetii)*	BLM NV	Upland	—	—	X	—	No, this species occurs in upland habitats outside of areas affected by any alternatives (GBIF 2004).
Tecate cypress *(Hesperocyparis forbesii)*	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (UC Berkeley 2025c).
Tecate tarplant *(Deinandra floribunda)*	BLM CA	Upland	—	—	—	—	No, this species grows in upland habitats which would not be affected by any alternative (NatureServe 2025www).
Tecopa salty bird's beak *(Chloropyron tecopense)*	BLM NV	Upland	—	—	—	—	No, this species' range is outside of the analysis area (CNPS 2025m).
Threecorner milkvetch *(Astragalus geyeri var. triquetrus)*	BLM NV, LCR MSCP	Marsh	—	—	X	—	Yes, this species is found along the shores of Lake Mead (D'Ambrosi 2023).
Tumamoc globeberry *(Tumamoca macdougalii)*	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025xxx).
Variegated dudleya *(Dudleya variegata)*	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternatives (NatureServe 2025yyy).

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Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Virgin River thistle *(Cirsium virginense)*	BLM NV	Woody Riparian	—	X	—	—	No, although this species occurs in hanging gardens, its range is along the Virgin River (Arizona Rare Plant Committee n.d.).
White bearpoppy *(Arctomecon merriamii)*	BLM NV	Upland	—	—	—	—	No, this species grows in upland habitat which would not be affected by any alternative (NatureServe 2025zzz).
Whitemargined beardtongue *(Penstemon albomarginatus)*	BLM NV	Upland	—	—	—	—	No, this species grows in upland sand and dune habitats which would not be affected by any alternative (NatureServe 2025aaaa).
White-bracted spineflower *(Chorizanthe xanti var. leucotheca)*	BLM CA	Upland	—	—	—	—	No, this species grows in upland habitat which would not be affected by any alternative (NatureServe 2025bbbb).
Wiggins' croton *(Croton wigginsii)*	BLM CA	Woody Riparian	—	—	—	X (7)	Yes, this species grows in sandy arroyos and has been observed within 200m of the Colorado River (NatureServe 2025cccc).
Yellow twotone beardtongue *(Penstemon bicolor ssp. bicolor)*	BLM NV	Upland	—	—	X	X (2)	Yes, this species may be found within full pool of Lake Mead (NatureServe 2025dddd).
Yucaipa onion *(Allium marvinii)*	BLM CA	Upland	—	—	—	—	No, this species grows in upland habitat which would not be affected by any alternative (SEINet 2025ff).

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TA 9 Attachment 2

Parker and Davis Dams DMDU Figures

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TA 9 Attachment 2. Parker and Davis Dams DMDU Figures

Figure TA 9 Attachment 2-1
Robustness Heat Map showing Davis Dam Max Annual Change in Release Variability in any 10-year Period

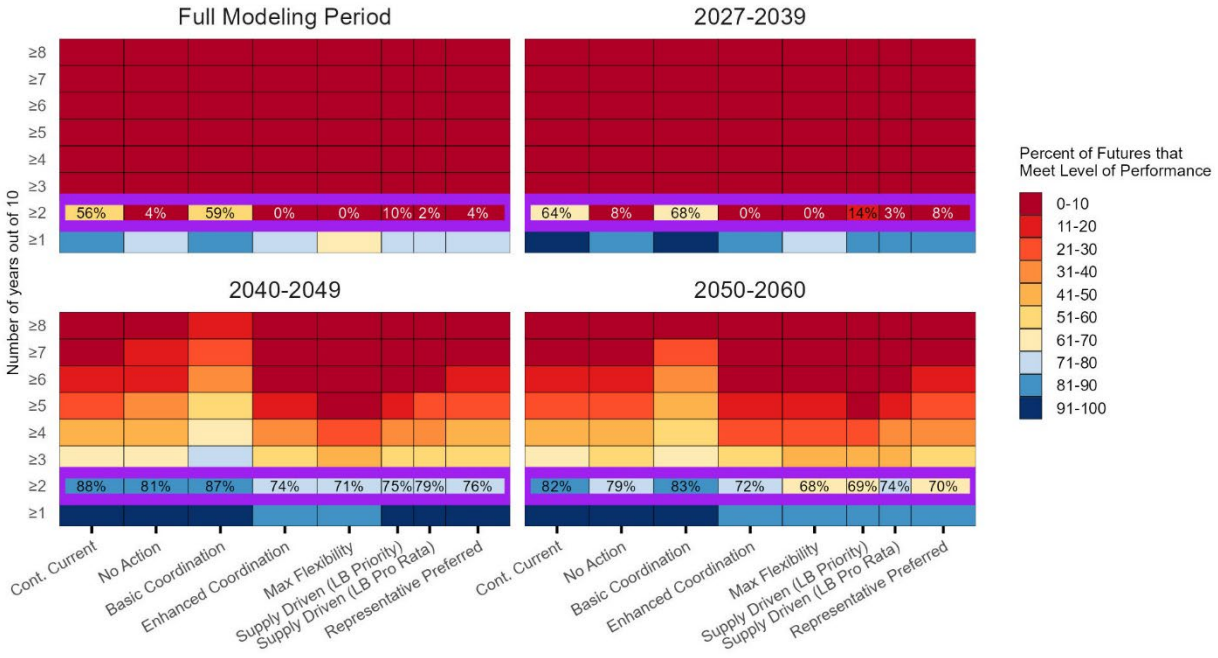


Figure TA 9 Attachment 2-2
Robustness Heat Map showing Davis Dam Max 5-year Change in Surface Elevation Variability in any 10-year Period

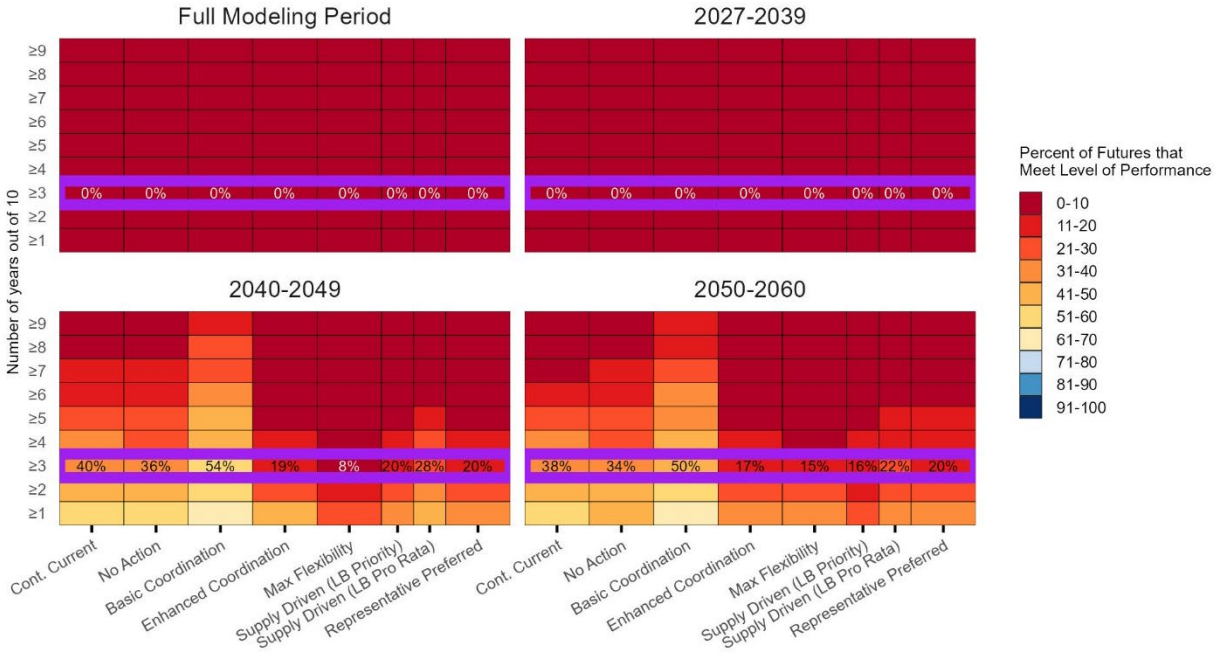


Figure TA 9 Attachment 2-3
Robustness Heat Map showing Parker Dam Max Annual Change in Release Variability in any 10-year Period

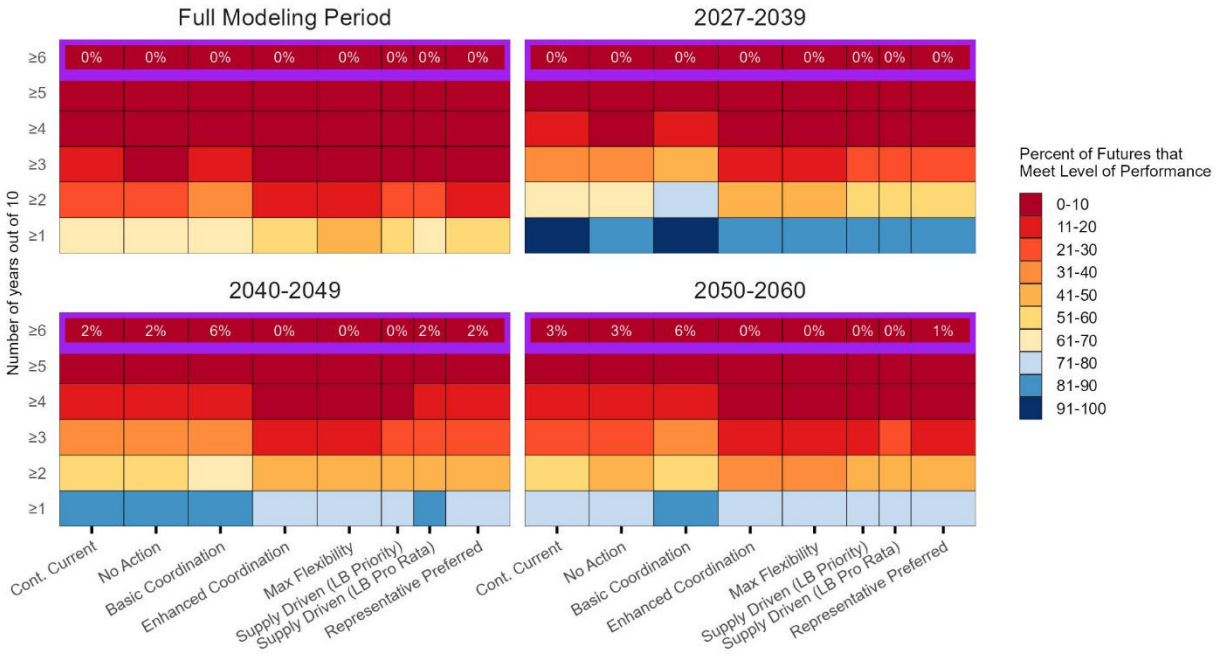
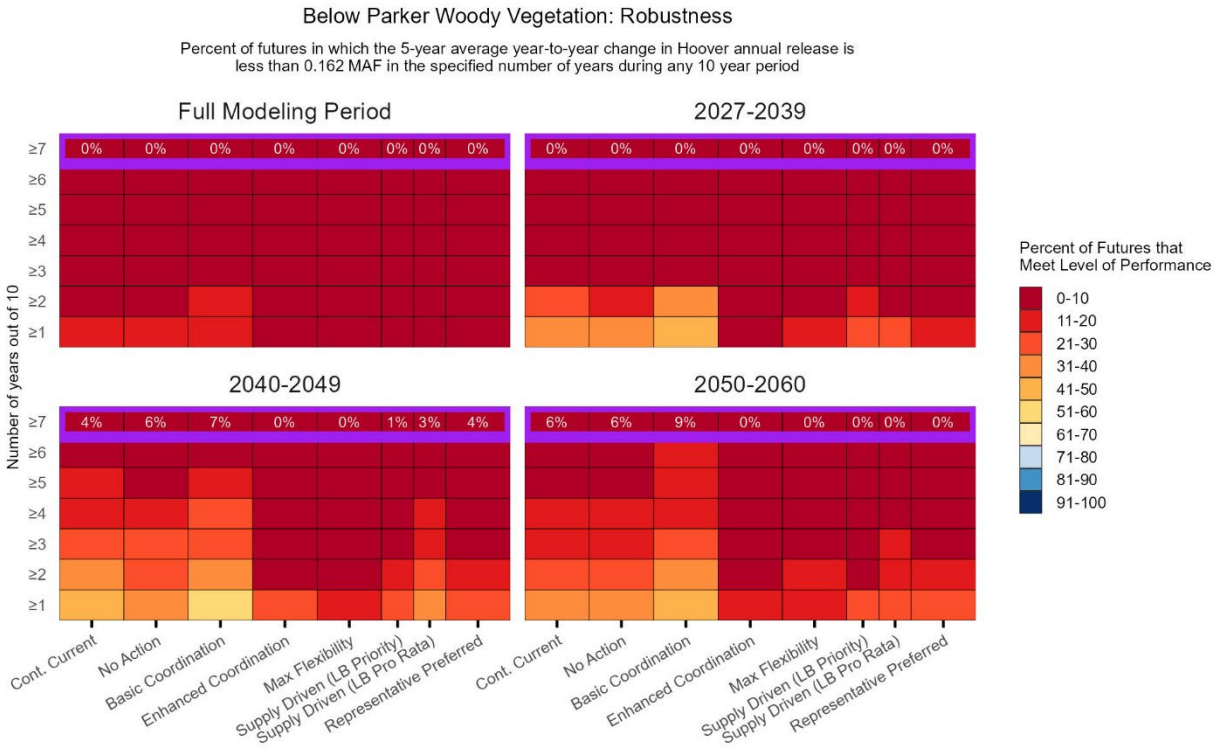


Figure TA 9 Attachment 2-4
Robustness Heat Map showing Parker Dam Max 5-year Change in Surface Elevation Variability in any 10-year Period



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Technical Appendix 10

Terrestrial Wildlife Including Special Status Species

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Attachment

TA 10 Attachment 1. Special Status Wildlife Species

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 FEIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
AZ	Arizona
BLM	Bureau of Land Management
BO	biological opinion
CA	California
CSC	California Species of Concern
ESA	Endangered Species Act
FWS	United States Fish and Wildlife Service
HCP	Habitat Conservation Plan
km	kilometer
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
maf	million acre-feet
NIB	Northerly International Boundary
SIB	Southerly International Boundary
U.S.	United States
UT	Utah

TA 10. Terrestrial Wildlife Including Special Status Species

TA 10.1 Affected Environment

This section provides an overview of the general terrestrial wildlife typically found within marsh, woody riparian, and upland habitats in the analysis area, as described in **Section TA 9.2** in **TA 9**, Vegetation Including Special Status Species. These general terrestrial wildlife include invertebrates, amphibians, reptiles, birds, and mammals. This section also includes special status species, which are defined here as those listed as Bureau of Land Management (BLM) sensitive species by the overlapping Arizona, California, Utah, and Nevada BLM field offices; species covered under the Lower Colorado River Multi-Species Conservation Program (LCR MSCP); and species listed as threatened or endangered or proposed for listing by the United States (U.S.) Fish and Wildlife Service (FWS; BLM 2017, 2018, 2019, 2023; LCR MSCP 2022; FWS 2025). **Attachment 1** in this technical appendix provides a table of the species considered in this document, including their listing status, the river reaches they typically inhabit, and the habitat types most important to their life histories. **Attachment 1** in this technical appendix was developed with input from cooperating agencies and local experts.

In addition to analyzing the impacts on wildlife in the analysis area as defined in the Vegetation section (see **Section TA 9.2** in **TA 9**, Vegetation Including Special Status Species), impacts are also evaluated for the LCR MSCP conservation areas. These areas were established to provide habitat for species listed under the Endangered Species Act (ESA) or that may become listed under the ESA and that use habitat along the Colorado River from Lake Mead down to the Southerly International Boundary (SIB; LCR MSCP 2025). The Colorado River in this area has been highly modified by several dams and water diversions, which have affected the growth and establishment of marsh and woody riparian habitat (see **Section TA 9.1** in **TA 9**, Vegetation Including Special Status Species).

The LCR MSCP Habitat Conservation Plan (HCP) and subsequent ESA consultations identified the impacts on marsh, woody riparian, upland, and backwater habitats predicted from existing and anticipated future river operations, and the program established the conservation areas and off-river land acquisitions to mitigate for these losses and provide reliable suitable habitat for wildlife (LCR MSCP 2025). There are 18 conservation areas aimed at conserving 27 species, with a goal of creating 5,940 acres of cottonwood and willow, 1,320 acres of honey mesquite, 568 acres of marsh, and 484 acres of backwater habitats. In addition to the conservation areas, several wildlife refuges and lands managed for wildlife are present below Hoover Dam. These include Havasu National Wildlife Refuge, Bill Williams River National Wildlife Refuge, Cibola National Wildlife Refuge, Imperial National Wildlife Refuge, Gooseflats Wildlife Area, Lake Mead National Recreation Area, and Mittry Lake Wildlife Management Area.

TA 9, Vegetation Including Special Status Species, describes the marsh, woody riparian, and upland habitat types, which are used in this section to determine the affected environment and environmental impacts on wildlife, including special status species.

TA 10.1.1 Marsh Habitat

See **TA 9**, Vegetation Including Special Status Species, for a description of marsh habitat. There are approximately 4,327 acres of marsh habitat in the analysis area (**Table TA 9-1** in **TA 9**, Vegetation Including Special Status Species). Marsh habitat can be vulnerable to harmful algal blooms due to increased water temperature and nutrient input. Harmful algal blooms can reduce water quality that can impact marsh vegetation, in turn reducing habitat quality and quantity for wildlife. Harmful algal blooms can also cause toxic water conditions that can be harmful to wildlife that contact or drink the water (CRS 2020). See **TA 6**, Water Quality, for more information on harmful algal blooms.

Invertebrates. Marshes are rich in invertebrate diversity, including mosquitoes (family Culicidae), water beetles (family Hydrophilidae), and midges (family Chironomidae). Many aquatic invertebrates use marsh habitat to lay eggs. These invertebrates are a vital part of the food web, supporting a variety of other wildlife species, including special status species and aquatic species, which are described in further detail in **TA 8**, Biological Resources – Fish and Other Aquatic Resources. Four special status invertebrate species predominantly use marsh habitat (**TA 10, Attachment 1**).

Amphibians and Reptiles. Marsh habitat along the Colorado River provides important resources for amphibian and reptile life stages. Amphibians lay eggs in standing water, where aquatic vegetation offers shelter and protection for eggs and developing larvae. Marshes also serve as important refuges for juvenile amphibians and reptiles, providing abundant food sources like insects and small invertebrates, which are crucial for growth and development. For reptiles, marshes offer both a food-rich environment and opportunities for thermoregulation. These areas are particularly valuable during the breeding season, providing critical hydration and temporary refuges during extreme temperatures.

Ten special status amphibians and reptiles predominantly use marsh habitat, including the northern Mexican gartersnake (*Thamnophis eques megalops*), which is a federally threatened species (**Table TA 9-1**). Northern Mexican gartersnakes use marsh habitat along large rivers and tributaries where they forage for fish, amphibians, lizards, small mammals, and invertebrates (AZGFD 2023). Northern Mexican gartersnakes are difficult to detect, and their occupied range along the Colorado River is unknown, although known occurrences existed within the Lake Havasu National Wildlife Refuge in 2015 and 2019 (LCR MSCP 2020; FWS 2024). It is assumed northern Mexican gartersnakes could be present in the analysis area within the Hoover Dam to the SIB reach (**TA 10, Attachment 1**). Minnow trapping was conducted in 2024 in previously occupied habitat, and ongoing camera trapping surveys are occurring at Topock Marsh. The 2024 and 2025 surveys resulted in no detections of this species (Sabin 2025).

The introduction and spread of aquatic invasive species have affected amphibian populations in the Colorado River system, which can affect species that prey on amphibians, such as the northern Mexican gartersnake (Reclamation 2024, Section 3.8, Aquatics). Nonnative fish prey on native

amphibian eggs, larvae, or adults. Common predatory aquatic invasive species are detailed in **TA 8**, Biological Resources – Fish and Other Aquatic Resources.

Birds. Marshes provide essential nesting sites for waterfowl and other wetland-dependent bird species. These birds depend on dense vegetation to conceal their nests from predators and provide suitable areas for raising their young (Hinojosa-Huerta 2004). Migratory birds use marsh habitat as stopover sites for resting, foraging, breeding, and nesting. Twelve special status species predominantly use marsh habitat, including Yuma Ridgway's rail (*Rallus obsoletus yumanensis*), which is a federally listed endangered species (**TA 10, Attachment 1**). Yuma Ridgway's rails use marsh habitat for both foraging and nesting, typically in areas dominated by cattails (*Typha* sp.) and bulrushes (*Scirpus* spp.; FWS 2009).

Within the analysis area, Yuma Ridgway's rails are found in the Lake Mead to Hoover Dam and Davis Dam to the Northerly International Boundary (NIB) reaches. Most Yuma Ridgway's rails in the analysis area are found in the Davis Dam to NIB reach, which contained between 30 and 58 percent of the U.S. population from 1995 through 2013 (Reclamation 2023). Surveys conducted from 2006 through 2022 detected 120 to 339 Yuma Ridgway's rails annually between Davis and Imperial Dams (Reclamation 2023). Surveys at selected sites in the Davis Dam to NIB reach from 2023 through 2025 detected 43 to 78 Yuma Ridgway's rails annually (Kahl 2024, 2025a, 2025b, 2025c; Ronning 2025).

Yuma Ridgway's rail is a highly mobile species, with a subset of the lower Colorado River population exhibiting migratory movements. Although some rails flew over 900 kilometers (km; 559 miles) to wintering areas in the United Mexican States, the three rails that were documented returning to their breeding grounds all returned to within 32 km (20 miles) of their original capture locations (Harrity and Conway 2020). The readiness with which rails colonize habitats distant from established breeding sites is unclear.

Mammals. Mammals use marsh habitat for shelter, for foraging, and as a critical drinking water resource. This habitat also plays a role in the reproductive cycle of some species, such as beavers (*Castor canadensis*). Other species rely on the aquatic plants and invertebrates in marsh habitats as essential food sources. Three special status mammal species predominantly use marsh habitat (**TA 10, Attachment 1**).

TA 10.1.2 Woody Riparian Habitat

See **TA 9**, Vegetation Including Special Status Species, for a description of woody riparian habitat. There are approximately 48,827 acres of woody riparian habitat within the analysis area (**Table TA 9-1**). Similar to marsh habitat, woody riparian habitat is vulnerable to harmful algal blooms (CRS 2020), which can impact wildlife that use this habitat type.

Invertebrates. Woody riparian habitat supports a variety of common terrestrial invertebrates, including winged (*Pterygota*) and wingless (*Apterygota*) insects. These insects play a crucial role in the terrestrial ecosystem as both pollinators and as a food source for other wildlife, including special status species. Several insect species, such as mayflies (*Leptophlebiidae*), stoneflies (*Plecoptera*), caddisflies (*Limnephilidae*), cicadas (*Hemiptera*), dragonflies (*Anisoptera*), and beetles (*Coleoptera*), breed

in the woody riparian habitat along the Colorado River. These species take advantage of the vegetation, moisture, and organic matter that these environments provide. Woody riparian habitat also supports the adult life stages of aquatic insects that are an important part of the aquatic ecosystem, which is described in further detail in **TA 8**, Biological Resources – Fish and Other Aquatic Resources.

Thirty-two special status invertebrate species predominantly use woody riparian habitat, including the monarch butterfly (*Danaus plexippus*), which is a federally proposed threatened species (**TA 10, Attachment 1**). Monarch butterflies use milkweed (*Asclepias* spp.) that grows in a variety of upland habitat types for breeding habitat as well as other nectar-producing plants while foraging. In Arizona, monarch butterflies are present and seasonally abundant, having been recorded every month of the year when seasonal temperatures are conducive, including documented overwintering at riparian locales. Monarchs often occur near riparian areas or other locations that contain water, including around ciénegas, creeks, washes, roadside ditches, and irrigated gardens. Monarchs favor riparian areas and rivers for migration (Morris et al. 2015). Within the analysis area along the river, there are several known occurrences of monarch butterflies and known locations of milkweed that breeding monarchs could use (Western Monarch Mapper 2025; **TA 10, Attachment 1**).

Amphibians and Reptiles. Woody riparian habitat provides forage and cover for common reptile and amphibian species, such as turtles, snakes, frogs, and salamanders. The thick woody cover provides temperature regulation opportunities and habitat for food sources for reptiles and amphibians; these food sources include plants, small mammals, and invertebrates. Additionally, woody riparian habitat can be used by species that forage in adjacent habitat as cover to avoid predation. Ten special status amphibian or reptile species predominantly use woody riparian habitat (**TA 10, Attachment 1**).

Birds. Birds, including raptors, use woody riparian habitat along the Colorado River for nesting, foraging, and sheltering during migration. Bird species benefit from the rich resources and shelter provided by woody riparian habitats, which are crucial for foraging and nesting activities. Native riparian vegetation, such as cottonwoods and willows, offers nesting sites and cover, which are especially valuable for species that depend on dense canopy structures. This habitat structure is particularly important for raptors that rely on elevated branches for hunting perches and nesting sites. Twenty-three special status bird species predominantly use woody riparian habitat, including southwestern willow flycatcher (*Empidonax traillii extimus*), which is a federally listed endangered species, and western yellow-billed cuckoo (*Coccyzus americanus*), which is a federally listed threatened species (**Table TA 9-1**).

Southwestern willow flycatchers nest in dense riparian habitat near standing or slow-moving water in the Glen Canyon to Lake Mead, Lake Mead to Hoover Dam, and Davis Dam to Parker Dam reaches. Southwestern willow flycatchers are often identified in tamarisk-dominant riparian habitat along the above-mentioned reaches. Generally, the analysis area does not provide extensive stands of dense riparian habitat suitable for breeding southwestern willow flycatchers. Along lake margins, suitable habitats are generally limited to inflow areas. Newly established riparian vegetation can be used as breeding habitat by southwestern willow flycatchers within 3 years of establishment (Paxton et al. 2007).

Two southwestern willow flycatcher breeding sites have been documented within the analysis area in recent years: Lower Las Vegas Wash, in the Lake Mead reach, and Topock Marsh, which is in the Hoover Dam to the SIB reach. A single nesting pair was documented at Lower Las Vegas Wash in 2021 (SWCA 2022). Between two and six southwestern willow flycatcher pairs bred at Topock Marsh each year in 2018 through 2022 (McLeod et al. 2023). No breeding or resident southwestern willow flycatchers were confirmed in the analysis area in 2023 or 2024, although suspected southwestern willow flycatchers were detected at two spring-fed locations in the Glen Canyon Dam to Lake Mead reach in 2023 (McLeod and Pellegrini 2025; McLeod and Pellegrini in prep.; Terwilliger and Whyte 2023). Surveys of these spring-fed locations in 2025 resulted in no southwestern willow flycatcher detections (Robertson 2025).

Migrant and transient southwestern willow flycatchers could use woody riparian habitat throughout the Glen Canyon to Lake Mead and Davis Dam to SIB reaches. Southwestern willow flycatchers readily colonize new suitable habitats that are near established breeding sites, but long-distance movements are relatively rare. Southwestern willow flycatchers exhibit fidelity to local areas, commonly returning from the wintering grounds to breed at the same site where they held a territory in the previous year. Half of adult returns in the lower Colorado River region in 1998 through 2012 resulted in movements of 40 meters (131 feet) or less, and less than 20 percent of movements were greater than 1 km (0.6 miles). Movements between 100 and 259 km (62 and 161 miles) were recorded in approximately 2 percent of cases. Average natal dispersal distances were greater than adult movement distances, although 90 percent of recorded dispersal movements were 75 km (47 miles) or less (McLeod and Pellegrini 2013). Because long-distance movements are uncommon, one southwestern willow flycatcher recovery strategy is to establish habitat close to existing breeding sites to increase the likelihood of colonization (FWS 2002:75).

Western yellow-billed cuckoos nest in riparian woodlands with mature willow and cottonwood from Glen Canyon Dam to Hoover Dam and Davis Dam to NIB. Western yellow-billed cuckoos nest in blocks of riparian woodland that are usually 50 acres or larger (Halterman et al. 2016; *Federal Register* 78:61633). Occupied lowland riparian habitat generally consists of mature willow and cottonwood forest, although other riparian tree species, such as mesquite and tamarisk, may also be present. Breeding habitat generally has both overstory and understory components (*Federal Register* 79:60010–60011), and nest locations typically have high canopy closure (McNeil et al. 2013). Large prey items, such as cicadas, katydids, grasshoppers, and caterpillars, form the bulk of the cuckoos' diet (*Federal Register* 78:61632).

Extensive riparian woodlands suitable for western yellow-billed cuckoo breeding are currently present only in LCR MSCP conservation areas from Davis Dam to the NIB (see LCR MSCP 2022 for a description of the conservation areas), where cuckoos begin using cottonwood-willow habitats after two growing seasons (McNeil et al. 2013). Surveys of the conservation areas in 2018 through 2022 resulted in an estimated 46 to 66 western yellow-billed cuckoo territories annually (Parametrix and Southern Sierra Research Station 2019; Tracy et al. 2023). Since the comprehensive surveys of the conservation areas completed in 2022, the Bureau of Reclamation has surveyed several conservation areas each year and continues to detect the species in suitable habitat. A single possible western yellow-billed cuckoo territory was documented at Lower Las Vegas in 2021 (SWCA 2022).

Migrant and transient yellow-billed cuckoos could use woody riparian habitat throughout the Glen Canyon to Lake Mead and Davis Dam to the SIB reaches. Yellow-billed cuckoo is a highly mobile species and able to move to suitable habitats wherever these habitats are available. Dispersal data from 19 yellow-billed cuckoos along the lower Colorado River indicate that while most between-year returns were to the same or adjacent sites, three movements of approximately 40 km (25 miles) were recorded, and one movement of approximately 75 km (47 miles) was recorded (Tracy et al. 2023). Yellow-billed cuckoos were documented using previous breeding habitat areas and colonizing new habitats at conservation areas along the lower Colorado River from 2008 to 2018 (LCR MSCP 2019). These observations provide evidence that the cuckoos' selection of breeding sites is not restricted to previous breeding areas, and they may be able to use suitable habitat wherever available.

Mammals. Mammals along the Colorado River rely on woody riparian habitat for shelter, food, breeding, young rearing, and movement corridors. These areas provide resources that support a diverse range of species, from small rodents to large herbivores, such as bighorn sheep (*Ovis* spp.), and carnivores. They also support aquatic invertebrates, fish, and small mammals, which serve as prey for carnivores. Bats are particularly dependent on woody riparian habitats, using them as foraging grounds where bats feed on insects attracted to water sources and dense vegetation. Beavers (*Castor canadensis*) play a particularly important role in these ecosystems by using woody riparian vegetation to construct dams and lodges. These structures create ponds that enhance water availability, benefiting many other species. Twenty-seven special status mammals, all bats, predominantly use woody riparian habitat (**TA 10, Attachment 1**).

TA 10.1.3 Upland Habitat

Upland habitat is described in **TA 9**, Vegetation Including Special Status Species, and is predominantly characterized as desert scrub in the analysis area. There are approximately 120,266 acres of upland habitat within the analysis area (**Table TA 9-1**).

Invertebrates. Desert scrub and upland habitat support a variety of invertebrates, including scorpions (*Scorpionidae* spp.), beetles (Coleoptera), and ants (*Formicidae* spp.). These invertebrates are key components of the desert ecosystem, serving as both predators and prey. Thirty-eight special status invertebrate species predominantly use upland habitat (**TA 10, Attachment 1**).

Amphibians and Reptiles. Amphibians and reptiles use upland habitat along the Colorado River for critical life-cycle activities, such as foraging, shelter, and breeding. While many species are closely tied to water sources for reproduction, some spend a significant portion of their lives in the surrounding uplands. The upland habitat along the Colorado River provides essential resources for a variety of reptile species, particularly those that rely on the region's rocky outcrops, sandy soil, and sparse vegetation, such as tortoises and lizards. These species use the sparse vegetation to hide from predators and shelter from extreme temperatures, and the sun-heated rocks provide a surface for basking and regulating body temperature. Fifteen special status amphibians and reptiles predominantly use desert scrub and upland habitat types, including the Mojave desert tortoise (*Gopherus agassizii*), a federally listed threatened species, and the Sonoran desert tortoise (*Gopherus morafkai*), a BLM sensitive species that is also protected under a candidate conservation agreement (FWS 2015; **TA 10, Attachment 1**).

Due to the difficulty in determining whether a tortoise is Mojave or Sonoran based on morphology alone, any tortoises found in the area immediately south and east of the Colorado River in northwest Arizona are listed as similarity of appearance (threatened) under the ESA (FWS 1990). Although the threatened Mojave desert tortoise population's range is defined as north and west of the Colorado River, recent genetic samples collected from tortoises near Lake Mead in Arizona were confirmed to be Mojave desert tortoise rather than Sonoran desert tortoise (FWS 2022). The Mojave and Sonoran desert tortoises are upland-obligate species that use open desert for burrowing and foraging, and they favor creosote bush (*Larrea tridentata*) habitats.

Birds. Desert scrub habitat along the Colorado River provides important nesting sites for several bird species. Additionally, some species actively forage for small mammals, reptiles, and insects within the scrub, often using the terrain's natural features, such as rock outcrops and sandy flats, to hunt and track prey. Desert scrub habitat also serves as habitat for breeding or as seasonal stopovers during migration. Twenty-four special status bird species predominantly use desert scrub and upland habitat; none are federally listed species (**TA 10, Attachment 1**).

Mammals. Small mammals use desert scrub for food and shelter, often using shrubs and low vegetation to hide from predators. The desert scrub also provides a variety of food sources, including grasses, shrubs, and seeds. Mice, rabbits, and other rodents use desert scrub environments to dig burrows to stay cool in the desert heat and for shelter from predators. Large mammals also use desert scrub for foraging and denning. Bats use desert scrub habitats for roosting and reproduction; they roost in rock crevices, abandoned buildings, or beneath the bark of trees found in desert scrub areas. Eleven special status mammal species predominantly use upland habitat; none are federally listed species (**TA 10, Attachment 1**).

TA 10.2 Environmental Consequences

TA 10.2.1 Methodology

This wildlife section relies on the outcomes of the vegetation analysis, the methodology for which is outlined in **Section TA 9.2.1**, Methodology, in **TA 9**, Vegetation Including Special Status Species.

Impact Analysis Area

The analysis area is the same as described in **Section TA 9.2.1**, Impact Analysis Area.

Assumptions

- The impacts analysis does not include upland wildlife species, including special status species, that do not rely directly on the Colorado River or on woody riparian and marsh vegetation influenced by elevation or flows. This is because changes in operations would not impact these species.
- The evaluation of impacts on wildlife, including special status species, is driven by impacts on the vegetation modeling in **Section 3.9** (vegetation analysis based on Decision Making under Deep Uncertainty).

Impact Indicators

These indicators align with the Decision Making under Deep Uncertainty figures in **Section 3.9**.

- For terrestrial wildlife species using marsh habitat, changes in water fluctuations within a single year compared with historical conditions
- For terrestrial wildlife species using woody riparian habitat, changes in water fluctuations in the preceding 5 years compared with historical conditions
- For terrestrial wildlife species using upland habitat, changes in water fluctuations over either the preceding single year or preceding 5 years compared with historical conditions

TA 10.2.2 Issue 1: How would changes in the management of the Colorado River impact terrestrial wildlife species habitat availability, including for special status species?

Lake Powell

As discussed in **TA 9.2** in **TA 9**, Vegetation Including Special Status Species, Lake Powell's surface water elevations fluctuate on a short-term (annual) and long-term (5-year) scale that causes changes in water availability, which results in the establishment, re-establishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife, including special status species (hereafter referred to as wildlife), that currently use the Lake Powell analysis area have adapted to these changing conditions.

Under all alternatives, modeling indicates a greater range of variability in Lake Powell's surface elevations compared to historic conditions for both marsh and woody riparian habitat in the first decade (2027–2039) (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-7** and **TA 9-8**). As described in **TA 9.2** in **TA 9**, Vegetation Including Special Status Species, this greater variability would result in changes in the vegetation extent compared to existing conditions, and could decrease vegetation cover. While Lake Powell would continue to support at least some upland, marsh, and woody riparian habitat, the location of where conditions are suitable to support each of these habitat types is likely to change. Areas that currently support marsh, woody riparian, or upland habitat could transition to one of the other habitat types. Side canyons that have been exposed due to lower water levels have had an increase in native vegetation, which likely provides suitable wildlife habitat for a range of wildlife species. An increase in water levels could result in the loss of suitable habitat in these areas.

With increased variability, wildlife would have to adapt to changing habitat availability on a larger scale than under historical conditions. For those species capable of moving long distances, such as large mammals, bats, birds, and some amphibians, reptiles, and invertebrates, this change in habitat availability would likely have less long-term impacts provided that suitable habitat is available within their dispersal or migratory range. This could also result in the range expansion or contraction of some species, including into new reaches, as they adapt to changing habitat availability. For less mobile species, such as some small mammals, amphibians, reptiles, and invertebrates, the transition from one habitat type to another may impact foraging, breeding, or sheltering behaviors, which can impact survival and reproduction. Decreased survival and reproduction on a large-scale can result in a decreased population size. Smaller local populations are more vulnerable to changes in the

environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

During the second (2040–2049) and third (2050–2060) decades, modeling indicates a range of variability more similar to historical conditions for the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative compared to the other alternatives as well as compared to the first decade (2027–2039; **TA 9**, Vegetation Including Special Status Species, **Figures TA 9-7** and **TA 9-8**). This would result in habitat variability similar to what is currently on the landscape; wildlife would need to adapt to changing habitat conditions at the same scale as historical conditions. For all other alternatives, variability would remain high in the second (2040–2049) and third (2050–2060) decades (as indicated by lower percentages of futures meeting the level of performance), and wildlife would continue to need to adapt to changing habitat availability on a larger scale compared to historical conditions.

In addition to the annual and 5-year changes in water elevation, modeling indicates Lake Powell would gradually rise in elevation over time under the Enhanced Coordination and Maximum Operational Flexibility Alternatives in all but the Critically Dry Flow Category (**TA 3.2** in **TA 3**, Hydrologic Resources, **Table TA 3-3 and TA 3.1, Figure TA 3-1s**). This would result in a shift of marsh and woody riparian vegetation along the new shoreline over time. The rise in water elevation would result in a marginal loss of upland habitat, but is not likely to impact wildlife that use marsh or woody riparian habitat, as the shift would be gradual enough for vegetation to continue to re-establish along the new shoreline. Under all other alternatives, modeling indicates water levels would remain the same or decrease in elevation. Similarly, vegetation would re-establish along the lower shoreline as the water elevations change over time. As water elevations lower, the distance to water for upland species would increase. However, given the ability for vegetation to adapt to changing water levels, this change in water elevation, either to a higher elevation under the Enhanced Coordination or Maximum Operational Flexibility Alternatives or to a similar or lower elevation under all other alternatives, is not likely to impact foraging, breeding, or sheltering behaviors for wildlife. Lower water levels can raise the risk of harmful algal blooms. This risk applies to all alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives and under all conditions except for the Critically Dry Flow Category. This could impact wildlife directly through increased toxicity exposure or indirectly through reductions in habitat quality and quantity.

While monarch butterfly primarily use woody riparian habitat for migration, they also use marsh and upland habitat regularly. Given the shifting availability of marsh, woody riparian, and upland habitat, and the ability to use features from all three habitat types, monarch butterflies are likely to be able to find suitable habitat under all alternatives in the Lake Powell analysis area. Species specific impacts will be addressed in future Section 7 ESA biological opinions (BOs).

Glen Canyon Dam to Lake Mead

Similar to Lake Powell, the Glen Canyon Dam to Lake Mead reach experiences fluctuating water levels that cause changes in water availability, which results in the establishment, re-establishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Glen Canyon Dam to Lake Mead analysis area have had to adapt to these changing conditions in the past.

As shown in **TA 9**, Vegetation Including Special Status Species, **Figures TA 9-9** and **TA 9-10**, the amount of suitable habitat for marsh and woody riparian vegetation across all three sub-reaches of the Glen Canyon Dam to Lake Mead reach is modeled to respond similarly under all alternatives, and the wide interquartile ranges in **TA 9**, Vegetation Including Special Status Species, **Figure TA 9-10** indicates that future acreages of woody riparian habitat are difficult to predict. For marsh and woody vegetation, for all alternatives and sub-reaches, there is less suitable habitat under the Wet and Moderately Wet Flow Categories and more suitable habitat under the Dry and Critically Dry Flow Categories compared to modeled historical conditions. The western Grand Canyon sub-reach has wider interquartile ranges, which suggests greater uncertainty in how vegetation will respond under the various alternatives. Woody vegetation has larger interquartile ranges than marsh vegetation, and therefore greater uncertainty. The amount of habitat available for wildlife species, including southwestern willow flycatcher and yellow-billed cuckoo, is affected primarily by modeled conditions rather than by the alternatives. Species specific impacts will be addressed in future Section 7 ESA BOs.

Similar patterns are apparent for native species richness, proportion of native species cover, and annual total vegetation cover (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-12**, **TA 9-13**, and **TA 9-14**). Increased species richness, proportion of native species cover, and annual total vegetation cover would be beneficial to wildlife species for foraging and breeding habitat. However, increasing each of these factors is driven by the modeled conditions rather than by the alternatives, with additional habitat available under the Critically Dry Flow Category. This is likely due to encroachment of vegetation into areas exposed by lower water levels.

With potentially decreasing water levels at Lake Powell, the temperature of releases from Glen Canyon Dam could increase, increasing the potential for harmful algal blooms in the Glen Canyon Dam to Lake Mead reach. Harmful algal blooms could impact wildlife directly through increased toxicity exposure or indirectly by reducing habitat quality and quantity (see **TA 6**, Water Quality).

Lake Mead

Similar to Lake Powell, Lake Mead experiences fluctuating water levels on an annual and 5-year time scale that cause changes in water availability, which results in the establishment, re-establishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Lake Mead analysis area have had to adapt to these changing conditions in the past. As described for Lake Powell, the first decade (2027–2039) exhibits higher variability compared to historical conditions under all alternatives, which would result in changes in habitat availability on a larger scale compared to existing conditions (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-7** and **TA 9-8**). Marsh and woody riparian vegetation is expected to decrease in response to the increase in variability.

Wildlife species that are capable of moving longer distances would be less likely to be affected by increased variability provided that suitable habitat is available within their dispersal or migratory range. Even for species that are highly mobile, there may be energetic costs to finding suitable habitat in a fragmented landscape if the distance between suitable habitat is outside their typical movement patterns. Increased energetic costs can impact survival and reproduction. Species that are less mobile may experience impacts on foraging, breeding, or sheltering behaviors, which can also

impact survival and reproduction. Decreased survival and reproduction through increased energetic costs while searching for suitable habitat or through impacts on foraging, breeding, or sheltering behaviors can result in a decreased population size. Smaller local populations are more vulnerable to changes in the environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

Unlike Lake Powell, the second (2040–2049) and third (2050–2060) decades exhibit variability similar to historical conditions for the Basic Coordination and Maximum Operational Flexibility Alternatives, rather than the Enhanced Coordination and Maximum Operational Flexibility Alternatives. However, the impacts on wildlife would be the same as described under Lake Powell for the Enhanced Coordination and Maximum Operational Flexibility Alternatives. That is, wildlife would need to adapt to changing habitat conditions at a rate more similar to historical conditions under the Basic Coordination and Maximum Operational Flexibility Alternatives, and would need to adapt to changing habitat conditions on a larger scale for the remaining alternatives.

As described in **TA 9.2** in **TA 9**, Vegetation Including Special Status Species, for all alternatives, Lake Mead elevations could rise, fall, or remain the same compared to existing conditions under all alternatives (**TA 3.2** in **TA 3**, Hydrologic Resources, **Figure TA 3-11**). Similar to Lake Powell, whether the water elevations increase, decrease, or stay the same compared to existing conditions, wildlife would likely be able to adapt to these slower changes and follow the vegetation as it reestablishes along the shoreline. Should water elevations decrease under any of the alternatives, the lowering of the water elevation in Lake Mead could increase the potential for harmful algal blooms, which could impact wildlife directly through increased toxicity exposure or indirectly through reduced habitat quality and quantity.

Listed threatened and endangered species with potential to occur in the Lake Mead analysis area consist of southwestern willow flycatcher, yellow-billed cuckoo, Yuma Ridgway's rail, and Mojave desert tortoise. Impacts have been previously assessed in the LCR MSCP HCP, Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 FEIS; Reclamation 2007), and 2004 SEIS and associated BOs. Additional Section 7 and Section 10 ESA processes are ongoing and additional impacts will be disclosed in future BOs and HCPs. Southwestern willow flycatcher and yellow-billed cuckoo rely on woody riparian habitat, which has modeled increased variability and therefore decreased habitat availability in the first decade (2027–2039) compared to historical conditions. These species are capable of moving long distances to access suitable habitat, although southwestern willow flycatchers exhibit local site fidelity and most readily colonize sites that are near existing breeding sites. The loss of suitable breeding habitat in a river reach could result in southwestern willow flycatchers being slow to recolonize the area even if suitable habitat redevelops. For both species, if water levels fluctuate or rise to the extent that habitat is unavailable, then impacts on nesting may occur. Yuma Ridgway's rails rely on marsh habitat, which may also experience increased variability and therefore decreased habitat availability in the first decade (2027–2039) compared to historical conditions. Yuma Ridgway's rails are also capable of moving long distances to access suitable habitat, although the readiness with which they colonize new areas far from established breeding sites is unclear. For all three species, as variability returns closer to historical conditions in the second (2040–2049) and third (2050–2060) decades for the Basic Coordination and Maximum

Operational Flexibility Alternatives, suitable habitat would likely be available similar to historical conditions.

Mojave desert tortoises rely on upland habitat. While upland habitat availability is modeled to change under all alternatives in each of the decades, Mojave desert tortoises would have suitable habitat available upslope and would be capable of moving away from rising water levels. Survivorship would depend on the quantity and quality of available forage in adjacent areas they would relocate to. As water levels fluctuate, upland habitat loss would be equal to the areas of change unless water fluctuations stabilized and upland vegetation was able to re-establish. Decreased survival and reproduction on a large-scale can result in a decreased population size. Smaller local populations are more vulnerable to changes in the environment, which can lead to even greater reductions in population size and an increased risk of the loss of local populations.

As described for Lake Powell, monarch butterflies are likely to find suitable habitat under each alternative and are unlikely to be affected.

Hoover Dam to the SIB

Similar to Lake Powell and Lake Mead, the Hoover Dam to the SIB reach experiences fluctuating water levels on an annual and 5-year timescale that causes changes in water availability, which results in the establishment, re-establishment, or loss of upland, marsh, and woody riparian habitat over time. Wildlife in the Hoover Dam to SIB analysis area had to adapt to these changing conditions in the past.

The LCR MSCP HCP and subsequent BOs set habitat creation goals to mitigate for predicted impacts from covered river operations including flow reductions, water delivery and diversion, changes in point of diversion, generation of hydropower, and operation and maintenance activities in the LCR MSCP planning area (Reclamation 2004; FWS 2005, 2018, 2022, 2024). A summary of the habitat creation goals and habitat created toward those goals as of 2025 (LCR MSCP 2025) are included as **Table TA 10-1**. Habitat creation goals assumed the predicted habitat impacts from reductions in flow and changes in points of diversion up to 2.083 million acre-feet (maf) per year may occur annually until 2055 and would be permanent, even if impacts never actually occur. Habitat would be created to replace it in LCR MSCP conservation areas. This includes a prediction that all existing cottonwood-willow land cover supported by the river and river connected groundwater would be lost due to flow-related covered activities (with the exception of habitat at Topock Marsh and Lake Havasu). Impacts to marsh from flow reductions from 2.083 maf per year to 3 maf per year were predicted to be short term in duration and the habitat would recover when inundated again (FWS 2024).

These habitat creation goals are the minimum amount of land cover to be created to meet the habitat requirements for the listed and unlisted species covered by the program. Habitat created by the LCR MSCP will be designed in an integrated mosaic and managed for more than one covered species, including habitat elements for each species.

Table TA 10-1
Summary of Habitat Creation Goals and Habitat Acres Created from Lake Mead to the SIB

Habitat Type	Habitat Creation Goal[1]	Acres Created through 2025[2]
Marsh	568	362
Woody Riparian (cottonwood-willow only)	5,940	4,954
Woody Riparian (honey mesquite only)	1,320	2,046
Woody Riparian (total)	7,260	7,000

Source: [1]Reclamation 2004; FWS 2005, 2022, 2024 [2]LCR MSCP 2020, 2025

Table TA 10-2 and **Table TA 10-3** demonstrate the amounts of acres affected, habitat created, and habitat creation commitments. Although it is unknown exactly how many acres of habitat will be affected over the next 30 years, referencing the amounts of acres affected over the last 20 years, the amount of habitat present in the reaches (**TA 9**, Vegetation Including Special Status Species, **Table TA 9-1**), and how those acres were mitigated, allows for a greater understanding of future implications. Future impacts and habitat creation commitments will be included in ESA Section 7 BOs and Section 10 HCPs.

Under all alternatives, all LCR MSCP conservation areas would retain their water entitlements. During shortage conditions, conservation areas with lower priority water rights (4th to 6th level priorities) may not receive their deliveries. Conservation areas are managed for the appropriate habitat type considering their water priority level and historic shortages decisions. During periods of shortage, there may be a reduction in habitat quality for areas with dense overstory and understory. When insufficient water is available, regardless of cause, to maintain established land cover types as habitat for one or more covered species, the Program Manager would coordinate with the FWS to prioritize the distribution of available water among created habitats to ensure that the greatest benefits for covered species would be provided. As water becomes available, the conservation areas would be managed to improve conditions. Currently, the Cibola Valley Conservation Area is the only LCR MSCP conservation area with 4th to 6th level priority water rights. Impacts to habitat quality if 4th to 6th level priority water rights may be minimized if groundwater is available to the roots of some or all of the vegetation. Current depth to groundwater in the Cibola Valley Conservation Area is approximately 10 feet.

As described for Lake Powell and Lake Mead, the first decade (2027–2039) exhibits high levels of variability compared to historical conditions for all alternatives, which would result in changes in habitat availability on a larger scale compared to existing conditions, especially for woody riparian habitat (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-17** and **TA 9-18**). Marsh and woody riparian habitat are modeled to decrease in the first decade in response to increased variability. Similar to Lake Mead, wildlife species could experience decreased population levels or localized population loss if the increased variability results in increased energy expenditure to find suitable habitat or impacts foraging, breeding, and sheltering behaviors.

Table TA 10-2
Summary of Federal and Nonfederal Flow-Related Affected Acres Included in 2004, 2018, 2022, and 2024 HCPs and BOs

Species	Federal and Nonfederal Flow-Related Impacts (acres) 2004				
Section 7 consultation	2004 BO and HCP[1]	Additional Impacts 2018 BA, BO and HCP[2]	Additional Impacts 2022 BA and BO[3]	Additional Impacts 2024[4] BA and BO	Total
Yuma Ridgway's rail	133	N/A	7	84[5]	224
Southwestern willow flycatcher	1,784	N/A	0[6]	0[7]	1,784
Yellow-billed cuckoo	1,425	N/A	0[8]	0[9]	1,420
Mojave desert tortoise	0	N/A	0[10]	0	0
Northern Mexican gartersnake	N/A	1081	7	84	1,172

[1] 2004 BO Table 2-56
[2] 2018 BO Tables 4-5 and 5-5 (same acres shared by Federal and Non-Federal assessments.
[3] 2022 BA
[4] 2025 BA
[5] The proposed action may have additional, temporary impacts on 16 acres of potential marsh habitat at Topock Marsh due to delayed completion of projects related to full implementation of AMM2, which was designed to avoid impacts of flow-related covered activities on covered species habitats at Topock Marsh (see Section 5.5.1.1 of LCR MSCP 2004b). Implementation of conservation measures, including creation of 41 acres of new marsh habitat and additional avoidance and minimization measures, will offset the effects of reduction in flow.
[6] Almost all existing and potential habitat for the southwestern willow flycatcher that will be affected was previously analyzed, incidental take was issued, and mitigation was established under the LCR MSCP (LCR MSCP 2004a, FWS 2005); therefore, no additional impacts are anticipated beyond those already assessed.
[7] Almost all existing and potential habitat for the southwestern willow flycatcher that will be affected was previously analyzed (see Section 4), incidental take was issued, and mitigation was established under the LCR MSCP (Reclamation 2004, FWS 2005). An exception to this includes Topock Marsh, which was excluded from impacted habitat based on the implementation of AMM2. Increased reduction in flow may temporarily affect 10.9 acres of southwestern willow flycatcher breeding sites at Topock Marsh due to delayed completion of projects related to full implementation of AMM2, which was designed to avoid impacts of flow-related covered activities on covered species habitats at Topock Marsh (see Section 5.5.2.1 of LCR MSCP 2004b). Implementation of avoidance and minimization conservation measures and continued implementation of the LCR MSCP will offset the effects of reduction in flow.
[8] The original LCR MSCP analysis assumed the loss of almost all cottonwood-willow existing and potential habitat for the western yellow-billed cuckoo that will be affected was previously analyzed (see Section 4), incidental take was issued, and mitigation was established under the LCR MSCP (2005); therefore, no additional impacts are anticipated beyond those already assessed.
[9] Almost all cottonwood-willow existing and potential habitat for the western yellow-billed cuckoo that will be affected was previously analyzed (see Section 4), incidental take was issued, and mitigation was established under the LCR MSCP (2005). An exception to this includes Topock Marsh which was excluded from impacted habitat based on the implementation of AMM2. Increased reduction in flow may temporarily affect 133 acres of potential cottonwood-willow habitat at Topock Marsh due to delayed completion of projects related to full implementation of AMM2, which was designed to avoid impacts of flow-related covered activities on covered species habitats at Topock Marsh (see Section 5.5.14.1 of LCR MSCP 2004b). Implementation of avoidance and minimization conservation measures and continued implementation of the LCR MSCP will offset the effects of reduction in flow
[10] Is not affected by flow related covered activities.

Table TA 10-3
ESA Section 7 Habitat Creation Commitments and Habitat Created 2005–Present

Section 7 Habitat Creation Commitments (acres) - Conservation/Mitigation Commitments					LCR MSCP Land Cover Created for the Species (between 2005-2025) (acres)
2004 BO	2018 BO	2022 BO	2024 BO	Total	All[11] (created/creditable)
512	N/A	15	41	568	362
4050	N/A	0	0	4050	945
4050	N/A	0	0	4050	2553
230 acres of existing habitat protection[12]	N/A	0	0	230	230 acres purchased

In the later decades (2040–2049 and 2050–2060), for the Hoover Dam to SIB reach, all alternatives meet the minimum level of performance in 78 percent or more of futures for marsh habitat (**TA 9**, Vegetation Including Special Status Species, **Figure TA 9-17**). For woody riparian habitat, the Basic Coordination Alternative is the most robust. The impacts on wildlife would be the same as described for Lake Powell and Lake Mead; wildlife would need to adapt to changing habitat conditions at a rate more similar to historical conditions under the Basic Coordination Alternative and would need to adapt to changing habitat conditions on a larger scale for the remaining alternatives. This could impact wildlife through changes in foraging, breeding, or sheltering behaviors, which can impact survival and reproductive rates of individuals. Decreased survival and reproduction on a large-scale can have population-level impacts.

Under all alternatives, flows from Hoover Dam to the SIB are modeled to decrease under the Average and Dry Flow Categories (**Table TA 3-21** and **Figure TA 3-27**, **TA 3.2** in **TA 3**, Hydrologic Resources). As described in **TA 9.2** in **TA 9**, Vegetation Including Special Status Species, a recent change analysis found that marsh vegetation decreased from 2000 to 2024 (RiverRestoration.org 2025). With a higher level of variability and decreased releases, marsh vegetation is modeled to continue to decrease over time and be replaced by either upland habitat or woody riparian habitat. Wildlife species that use marsh habitat in the Hoover Dam to SIB reach are modeled to experience greater levels of habitat loss than under historical conditions if future conditions are dry or average. This habitat loss could impact wildlife's ability to forage, breed, nest, and shelter in the area, causing them to relocate or possibly impact survival rates. The potential for decreased water levels in Lake Mead could also result in increased temperatures released from Hoover Dam. This could increase the potential for harmful algal blooms, which impact marsh and woody riparian vegetation, and could impact wildlife directly through increased toxicity exposure or indirectly through reductions in habitat quality and quantity.

[11] Lower Colorado River Multi-Species Conservation Program. 2025. Final Implementation Report, Fiscal Year 2026 Work Plan and Budget, Fiscal Year 2024 Accomplishment Report. Bureau of Reclamation, Boulder City, Nevada. Table 1-8

[12] Net loss in habitat is fully mitigated by protecting 230 acres of desert tortoise habitat in accordance with mitigation requirements in the document entitled "Compensation for Desert Tortoise" (Desert Tortoise Compensation Team 1991).

Federal, state, and tribal managed habitat areas, such as Cibola National Wildlife Refuge, depend on water from the Colorado River to ensure functional habitat for wildlife. If water in the river drops below the level at which water is able to properly flow through diversion structures or pumps are able to function, there may be impacts on habitat unless another method is used to transport water to the managed habitat areas. If a prolonged period of dryness occurs, woody riparian and marsh vegetation may begin to desiccate; however, the extent to which this will occur is unknown.

Listed threatened and endangered wildlife species that have the potential to occur in the Hoover Dam to the SIB analysis area are southwestern willow flycatcher, yellow-billed cuckoo, Yuma Ridgway's rail, northern Mexican gartersnake, and Mojave desert tortoise. Impacts have been previously assessed in the LCR MSCP HCP, 2007 FEIS, and 2004 SEIS and associated BOs. Additional Section 7 and Section 10 ESA processes are ongoing and additional impacts will be disclosed in future BOs and HCPs. Migrant and transient southwestern willow flycatchers and yellow-billed cuckoos could be affected by the general availability of woody riparian vegetation in which they forage and shelter, which is modeled to decrease in the first decade (2027–2039) under all alternatives (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-17** and **TA 9-18**). In the second (2040–2049) and third (2050–2060) decades, decreased cover of woody riparian vegetation is modeled under all alternatives, but to a lesser extent under the Basic Coordination Alternative, Continued Current Strategies Comparative Baseline, and Representative Preferred Alternative (**TA 9**, Vegetation Including Special Status Species, **Figures TA 9-12** and **TA 9-13**). Breeding southwestern willow flycatchers have been present in recent years at Topock Marsh, while breeding yellow-billed cuckoos are found in LCR MSCP conservation areas and other restored habitat. Woody riparian vegetation in these areas could be affected by the alternatives if they result in shortage allocation reductions of water deliveries. Alternatives that enhance habitat near established populations would benefit species such as the southwestern willow flycatcher that show fidelity to breeding sites. Reductions in water allocations to the conservation areas could reduce the amount of woody riparian habitat available for yellow-billed cuckoo breeding.

Decreased cover of marsh vegetation may occur in the first decade (2027–2039) for all alternatives, which could affect Yuma Ridgway's rail by reducing the amount of habitat available for breeding, feeding, and sheltering. Under all alternatives, marsh vegetation may re-establish in the later decades (2040–2049 and 2050–2059) to an extent similar to recent conditions. However, under dry to average future conditions, water is modeled to decrease over time under all alternatives, which could reduce the amount of habitat available for Yuma Ridgway's rails for breeding, feeding, and sheltering.

The most recent confirmed northern Mexican gartersnake sightings have been in Topock Marsh on the Havasu National Wildlife Refuge. Marsh vegetation at Topock Marsh could be affected by the alternatives if they result in shortage allocation reductions of water deliveries. Northern Mexican gartersnakes are less capable of moving long distances. Should a northern Mexican gartersnake be present in marsh habitat that experiences higher levels of variability that results in the loss of that marsh habitat, as is possible in the first decade (2027–2039) under all alternatives, northern Mexican gartersnakes may not be able to find suitable replacement habitat, which could cause local population loss. In the second (2040–2049) and third (2040–2049) decades, all alternatives would have conditions more similar to historical conditions, which may support northern Mexican

gartersnakes in a condition more similar to existing conditions. Mojave desert tortoise are likely to be able to move to upland habitat as the habitat conditions change over time.

Water levels are modeled to decrease under all alternatives under Average and Dry Flow Categories. This may result in additional upland habitat for Mojave desert tortoise. Similar to Lake Powell and Lake Mead, monarch butterfly is likely to find suitable habitat under each alternative and are unlikely to be affected.

TA 10.2.3 Summary Comparison of Alternatives

Changes in reservoir elevations and flow variability can alter the extent and location of marsh, woody riparian, and upland habitats that support terrestrial wildlife, including special status species. These habitat shifts affect wildlife by changing the availability of areas used for foraging, breeding, sheltering, and migration. While highly mobile species may relocate to suitable habitat, less mobile species may experience reduced survival or reproduction if habitat availability declines or becomes fragmented, which can reduce population sizes or lead to the loss of local wildlife.

For Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in wildlife habitat availability most similar to historical conditions (**TA 9**, Vegetation Including Special Status Species, **Table TA 9-1**). The Maximum Operational Flexibility Alternative would also result in wildlife habitat availability most similar to historical conditions for Lake Mead. However, for Hoover Dam to the SIB, the Maximum Operational Flexibility and Enhanced Coordination Alternatives would result in wildlife habitat availability least similar to historical conditions with subsequent impacts on wildlife foraging, breeding, or sheltering behaviors, which can reduce reproduction and survival of individuals. Similarly, the Basic Coordination Alternative would result in wildlife habitat least similar to historical conditions for Lake Powell, but would be closest to historical conditions for Lake Mead and Hoover Dam to the SIB. Therefore, no single alternative would result in wildlife habitat availability similar to historical conditions across all reaches. For all reaches, multiple alternatives provide variability more similar to historical conditions than the Continued Current Strategies Comparative Baseline except for the Hoover Dam to SIB reach, where only the Basic Coordination Alternative would result in variability more similar to historical conditions for woody riparian vegetation. This suggests that a change in management from current strategies would benefit a large portion of the analysis area, but would not benefit woody riparian vegetation in the Hoover Dam to SIB reach unless the Basic Coordination Alternative was selected.

Under all alternatives, the first decade (2027–2039) would experience more variability, which would likely result in a reduction of marsh and woody riparian habitat and therefore impacts on wildlife compared to historical conditions. All alternatives see conditions return to closer to historical conditions in the second (2040–2049) and third (2050–2060) decades, which would likely result in wildlife habitat reestablishing to a similar extent. Where variability eliminates or prevents establishment of marsh, woody riparian, or upland habitat, there may be a shift to one of the other habitat types.

For the Glen Canyon Dam to Lake Mead reach, the alternative that would result in wildlife habitat availability most similar to historic conditions depends strongly on flow categories. Under the Dry

Flow Category and Critically Dry Flow Category, some differences among the alternatives emerge, presumably because there are greater differences in the lowest flows, the median flows, and peak flows under those conditions. However, across all alternatives, all sub-reaches, and all evaluated criteria (suitable habitat area, native species richness, proportion native species cover, and annual total vegetation cover), the interquartile ranges of the alternatives often overlap. When the interquartile ranges overlap, it is difficult to say whether one alternative is truly different from another. Therefore, no single alternative emerged as the best or worst for retaining wildlife habitat similar to historic conditions.

For all reaches, a decrease in water elevation or flow could increase water temperatures, which would increase the potential for harmful algal blooms. Harmful algal blooms can cause direct impacts on wildlife through increased toxicity or indirect impacts through decreases in habitat quality and quantity. The Enhanced Coordination and Maximum Operational Flexibility Alternatives would have increased water levels in Lake Powell in all but the Critically Dry Flow Category, which would result in the lowest potential for a harmful algal bloom. For Lake Mead, all alternatives may result in a lowered elevation, which could increase the potential for a harmful algal bloom in Lake Mead and in the Hoover Dam to SIB reach.

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TA 10 Attachment 1

Special Status Wildlife Species List

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TA 10 Attachment 1. Special Status Wildlife Species

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Birds							
American peregrine falcon (*Falco peregrinus*)	Bureau of Land Management (BLM) Arizona (AZ), BLM Nevada (NV)	Woody Riparian	X	X	X	X	Yes, this species forages along the Colorado River corridor and could be affected by reductions in bat and bird populations associated with loss of riparian and marsh habitat (NDOW 2025a).
American white pelican (*Pelicanus erythrorhynchos*)	BLM Utah (UT)	Marsh	X	X	X	X	No, this species is migratory and does not breed in the analysis area (Van Tatenhove et al. 2025).
Arizona Bell's vireo (*Vireo bellii arizonae*)	BLM California (CA), BLM NV, LCR MSCP	Woody Riparian	X	X	X	X	Yes, the analysis area is within the spring and summer range of this species (LCR MSCP 2016).
Arizona grasshopper sparrow (*Ammodramus savannarum ammolegus*)	BLM AZ	Upland	—	X	X	X	No, this species is a migrant and does not breed within the analysis area. It would not be affected by any alternative (NatureServe 2025a).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Bald eagle (*Haliaeetus leucocephalus*)	BLM AZ, BLM NV, BLM UT	Woody Riparian	X	X	X	X	Yes, this species is present during winter months (November-February) in the Grand Canyon. They are present in winter and spring at Lake Mead, Lake Mohave and Lake Havasu (Buehler 2022).
Bank swallow (*Riparia riparia*)	BLM CA, BLM NV	Marsh	—	X	—	X	No, this species is a migrant that does not breed in the analysis area (Garrison and Turner 2020).
Bendire's thrasher (*Toxostoma bendirei*)	BLM CA, BLM NV, CA Species of Concern (CSC)	Upland	—	—	—	X	Yes, this species forages in riparian habitat (England & Laudenslayer 2020).
Black swift (*Cypseloides niger*)	BLM UT	Upland	X	—	—	—	No, this species forages over diverse habitat types. It nests behind waterfalls, which will not be affected by any alternative (Gunn et al. 2023).
Black-chinned sparrow (*Spizella atrogularis*)	BLM NV	Upland	X	X	—	—	No, this species is found in upland habitats such as desertscrub and pinyon-juniper woodlands, which will not be impacted by any alternative (Pandolfino et al. 2024).
Black-throated gray warbler (*Setophaga nigrescens*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species overwinters in cottonwood-willow habitat (Guzy and Lowther 2020).
Brewer's sparrow (*Spizella breweri*)	BLM NV	Upland	X	X	X	X	No, this species is found in diverse upland habitats which will not be impacted by any alternative (Rotenberry et al. 2020).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Broad-tailed hummingbird (*Selasphorus platycercus*)	BLM NV	Woody Riparian	—	X	—	—	Yes, this species breeds in riparian corridors in northern Arizona (Camfield et al. 2020).
Brown-crested flycatcher (*Myiarchus tyrannulus*)		Woody Riparian	—	X	X	X	Yes, the analysis area is within the breeding range of this species (Cardiff and Dittmann 2020).
Burrowing owl (*Athene cunicularia*)	BLM UT, BLM NV	Upland	X	—	X	X	Yes, this species utilizes desert habitat for foraging and nesting (Poulin et al. 2020).
Cactus ferruginous pygmy owl (*Glaucidium brasilianum cactorum*)	BLM AZ, threatened	Upland	—	—	—	—	No, the range for this species is outside of areas affected by any alternative (FWS 2025a).
California black rail (*Laterallus jamaicensis coturniculus*)	BLM AZ, BLM CA, LCR MSCP	Marsh	—	—	—	X	Yes, this species nests in marsh areas and the analysis area is within the species' range (Eddleman et al. 2020).
California brown pelican (*Pelecanus occidentalis californicus*)	BLM CA	Marsh	—	X	—	X	No, this species is rarely detected and does not breed in the analysis area (NPS 2022).
California condor (*Gymnogyps californianus*)	BLM AZ, endangered	Upland	X	X	—	—	Yes, this species breeds and nests within the Grand Canyon (FWS 2025b).
Cassin's finch (*Haemorhous cassinii*)	BLM NV	Upland	X	X	—	—	No, this species is found in pinyon-juniper and mixed-conifer forests which will not be affected by any alternative (Hahn 2020).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Clark's grebe (*Aechmophorus clarkii*)	ASC	Marsh	—	—	X	X	Yes, this species breeds in open marshes and forages in open water in reservoirs (LaPorte et al. 2020).
Common nighthawk (*Chordeiles minor*)	BLM NV	Upland	X	X	—	—	No, this species breeds in uplands which will not be affected by any alternative (Cornell 2025).
Crissal thrasher (*Toxostoma crissale*)	BLM CA, BLM NV	Woody Riparian	—	X	—	X	Yes, the analysis area is within the year-round range for this species (Bringham et al. 2020).
Elf owl (*Micrathene whitneyi*)	BLM CA, LCR MSCP	Woody Riparian	—	—	—	X	Yes, this species has been observed along and near Lake Havasu, Bill Williams River Delta, and near Yuma (McKernan and Braden 2002; Wise-Gervais 2005; MSCP 2010; Henry et al. 2020).
Ferruginous hawk (*Buteo regalis*)	BLM UT, BLM NV	Upland	X	X	—	—	No, this species forages over diverse habitat types. It nests on exposed cliffs or solitary trees or infrastructure, which will not be affected by any alternative (Ng et al. 2020).
Flammulated owl (*Psiloscopis flammeolus*)	BLM NV	Upland	—	X	—	—	No, this species is found in conifer forests which will not be affected by any alternative (Linkhart and McCallum 2020).
Gila woodpecker (*Melanerpes* uropygialis)	BLM CA, LCR MSCP	Woody Riparian	—	—	—	X	Yes, the analysis area is in the range of this species (Edwards and Schnell 2020).
Gilded flicker (*Colaptes chrysoides*)	BLM AZ, BLM NV, BLM CA	Woody Riparian	—	—	—	X	Yes, this species will nest in willow or cottonwood which may be affected (Moore et al. 2020).
Golden eagle (*Aquila chrysaetos*)	BLM UT, BLM NV, BLM AZ	Upland	X	X	X	X	Yes, although this species is rarely detected nesting (iNaturalist 2025a).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Grace's warbler (*Setophaga graciae*)	BLM NV	Upland	X	X	—	—	No, this species is found in conifer forests which will not be affected by any alternative (Staicer and Guzy 2020).
Great Basin willow flycatcher (*Empidonax traillii adastus*)	BLM NV	Woody Riparian	—	—	X	X	No, this species does not nest in the analysis area (NDOW 2025b).
Least bittern (*Ixobrychus exilis*)	BLM NV, LCR MSCP	Marsh	—	X	X	X	Yes, this species utilizes marsh habitat and breeds within the analysis area (FWS 2012; Poole et al. 2024).
LeConte's thrasher (*Toxostoma lecontei*)	BLM AZ, BLM NV	Upland	—	—	X	X	No, this species utilizes dry grassland and desert habitat for foraging and nesting, which will not be affected by any alternative (Sheppard 2020)
Lewis's woodpecker (*Melanerpes lewis*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species is found in riparian areas, and its range is within the analysis area (Vierling 2020).
Loggerhead shrike (*Lanius ludovicianus*)	CSC, BLM NV	Upland	X	X	X	X	No, this species is found in uplands (shrublands, desertscrub, grasslands) which will not be affected by any alternative (Yousef 2020).
Long-billed curlew (*Numenius americanus*)	BLM NV	Marsh	—	—	—	X	Yes, this species breeds in grasslands but migrates and overwinters in riverine marshes including lower Colorado River (Dugger and Dugger 2020).
Long-eared owl (*Asio otus*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species overwinters in willow and tamarisk which may be affected (Marks et al. 2020).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Lucy's warbler (*Vermivora luciae*)	BLM CA	Woody Riparian	X	X	—	X	Yes, although this species is rare, it has been observed in Lake Mead Recreation area and breeds in tamarisk which may be affected (Johnson et al. 2020).
Mountain plover (*Charadrius montanus*)	BLM CA	Upland	—	—	—	X	Yes, this species is present in the analysis area (FWS 2025c).
Northern goshawk (*Accipiter gentilis*)	BLM AZ	Upland	—	X	—	—	No, this species utilizes upland forested habitat with high canopy cover for foraging and nesting; this habitat will not be affected by any alternative (NDOW 2025c).
Northern harrier (*Circus cyaneus*)	CSC	Marsh		X	X	X	Yes, this species may be found in marshes during nonbreeding season (Smith et al. 2020).
Olive-sided flycatcher (*Contopus cooperi*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species uses riparian habitat during migration and its range is within the analysis area (Altman and Sallabanks 2020).
Phainopepla (*Phainopepla nitens*)	BLM NV	Woody Riparian	—	X	X	X	Yes, this species uses honey mesquite riparian habitat (Chu and Walsberg 2020).
Pinyon jay (*Gynorhinus cyanocephalus*)	BLM NV	Upland	X	X	—	—	No, this species is found in upland pinyon-juniper habitat which will not be affected by any alternative (Johnson and Sadoti 2023).
Sagebrush sparrow (*Atrtemisiospiza nevadadensis*)	BLM NV	Upland	X	X	X	X	No, this species is found in upland habitat which will not be affected by any alternative (Martin et al. 2025).
Sage thrasher (*Oreoscoptes montanus*)	BLM NV	Upland	X	X	X	X	No, this species is found in upland habitat which will not be affected by any alternative (Reynolds et al. 2020).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Scott's oriole (*Icterus parisorum*)	BLM NV	Upland	X	X	—	—	No, this species is found in upland oak/scrub habitat which will not be affected by any alternative (Flood 2020).
Short-eared owl (*Asio flammeus*)	BLM NV	Marsh	—	—	X	X	Yes, this species winters in marsh habitat which may be affected (Wiggins et al. 2020).
Sonoran yellow warbler (*Dendroica petechia sonorana*)	LCR MSCP	Woody Riparian	—	—	X	X	Yes, this species' breeding range exists in the lower Colorado River valley (Shuford and Gardali 2008).
Southwestern willow flycatcher (*Empidonax traillii extimus*)	BLM AZ, BLM CA, BLM NV, LCR MSCP, Endangered	Woody Riparian	—	X	X	X	Yes, this species is found in riparian areas across the southwest including Lake Mead and the lower Colorado River (FWS 2025d).
Summer tanager (*Piranga rubra*)	LCR MSCP	Woody Riparian	—	X	X	X	Yes, this species is found in the Colorado River area during breeding season (Audubon 2025a).
Swainson's hawk (*Buteo swainsoni*)	BLM CA, BLM NV	Upland	—	X	—	X	No, this species forages over diverse habitat types which will not be affected by any alternative (Bechard et al. 2020).
Tricolored blackbird (*Agelaius tricolor*)	BLM CA	Marsh	—	—	—	—	No, the analysis area is outside of the species' range (Audubon 2025b).
Verdin (*Auriparus flaviceps*)	BLM NV	Woody Riparian	—	—	X	X	Yes, this species nests in honey mesquite in the riparian woodland along the lower Colorado River (Webster 2020).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Vermilion flycatcher (*Pyrocephalus rubinus*)	LCR MSCP, CSC	Woody Riparian	—	—	X	X	Yes, this species utilizes riparian habitat and has been observed in Lake Mead Recreation area (NPSpecies 2011a) and in the Lower Colorado Region, including at Cibola National Wildlife Refuge, Region 5, and Region 12 (LCR MSCP 2021).
Virginia's warbler (*Leiothlypis virginiae*)	BLM NV	Upland	—	X	X	—	No, this species is found in upland pinyon-juniper habitat which will not be affected by any alternative (Audubon 2025c).
Western snowy plover (*Charadrius nivosus nivosus*)	BLM NV	Marsh	—	—	X	—	Yes, this species nested at the Overton Arm of Lake Mead in 2007 and often nests at the Salton Sea (FWS 2025e).
Western yellow-billed cuckoo (*Coccyzus americanus*)	BLM AZ, BLM CA, BLM NV, LCR MSCP, Threatened	Woody Riparian	—	X	X	X	Yes, this species occupies dense thickets along streams and marshes and has been observed along the Little Colorado River (Tracy and Squibb 2022).
White-tailed kite (*Elanus leucurus*)	BLM CA	Marsh	—	—	—	X	Yes, this species is present in the analysis area (CDFW 2025a).
Yellow-breasted chat (*Icteria virens*)	CSC	Woody Riparian	—	X	X	X	Yes, this species is found at Lake Mead, the Salton Sea, the Little Colorado River, and throughout the lower Colorado River region (LCR MSCP 2021; Thompson and Eckerle 2022).
Yuma Ridgway's rail (*Rallus obsoletus yumaniensis*)	BLM AZ, BLM CA, BLM NV, LCR MSCP, Endangered	Marsh	—	Historic	X	X	Yes, this species is a year-round resident of the Colorado and Gila River (Audubon 2025d).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Mammals							
Allen's big-eared bat (*Idionycteris phyllotis*)	BLM AZ, BLM NV, BLM UT	Woody Riparian	X	X	X	—	Yes, this species inhabits riparian areas above 3,000 feet (Carpenter et al. 2021; NDOW 2025d).
Arizona myotis (*Myotis occultus*)	BLM AZ, CSC	Marsh	X	X	X	X	Yes, while typically found at higher elevations (>1830 m), this species has been found in low elevation reaches of the Colorado and Verde rivers in Arizona (Carpenter et al. 2021; USFS 2014).
Big brown bat (*Eptesicus fuscus*)	BLM NV	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NPS 2017).
Big free-tailed bat (*Nyctinomops macrotis*)	BLM NV, CSC	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NatureServe 2025b).
Bighorn sheep (*Ovis* spp.)	BLM CA, BLM NV	Woody Riparian	X	X	X	X	Yes, these species utilize the Colorado River and associated reservoirs for water (NDOW 2025e).
California leaf-nosed bat (*Macrotus californicus*)	BLM AZ, BLM NV, LCR MSCP	Woody Riparian	—	X	X	X	Yes, this species can be found in the Colorado River valley (iNaturalist 2025b).
California myotis (*Myotis californicus*)	BLM NV	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (iNaturalist 2025c).
Canyon bat (*Parastrellus hesperus*)	BLM NV	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021, NABat*).
Cave myotis (*Myotis velifer*)	BLM AZ, BLM NV, CSC	Woody Riparian	X	X	X	X	Yes, however, this species has not been confirmed between Glen Canyon Dam and Lake Mead (iNaturalist 2025d).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Colorado River cotton rat (*Sigmodon arizonae plenus*)	LCR MSCP	Marsh	—	—	X	X	Yes, this species is often found near rivers and their floodplains and lakes and ponds (NatureServe 2025c).
Dark kangaroo mouse (*Microdipodops megacephalus*)	BLM NV	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NDOW 2025f).
Desert kangaroo rat (*Dipodomys deserti*)	BLM NV	Woody Riparian	—	—	X	X	No, this species is found in upland desertscrub habitat which will not be affected by any alternative (NatureServe 2025d).
Desert pocket mouse (*Chaetodipus penicillatus sobrinus*)	MSCP, BLM NV	Upland	—	—	X	X	Yes, this species occurs most often in soft alluvian, sandy, or silty soils along stream bottoms, desert washes, and valleys (ADW 2025*).
Fringed myotis (*Myotis thysanodes*)	BLM UT, BLM NV	Woody Riparian	X	X	X	—	Yes, this species has been observed in Lake Mead Recreation area (Carpenter et al. 2021; NPSpecies 2011b).
Greater western mastiff bat (*Eumops perotis californicus*)	CSC, BLM NV	Upland	X	X	—	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NatureServe 2025e).
Hoary bat (*Lasiurus cinereus*)	BLM NV	Upland	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NatureServe 2025f).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Houserock Valley chisel-toothed kangaroo rat (*Dipodomys microps leucotis*)	BLM AZ	Upland	—	—	—	—	No, this species utilizes dry and desert habitat types for foraging; these will not be affected by any alternative (NatureServe 2025g).
Inyo shrew (*Sorex tenellus*)	BLM NV	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025h).
Kawich pocket gopher (*Thomomys bottae brevidens*)	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (GBIF Secretariat 2024).
Kit fox (*Vulpes macrotis*)	BLM UT	Upland	X	X	X	X	Yes, this species has been observed at Lake Mead (NPSpecies 2011c).
Little brown bat (*Myotis lucifugus*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species feeds in woody riparian habitats and the analysis area is within its range (Carpenter et al. 2021; Lausen et al. 2008).
Long-eared myotis (*Myotis evotis*)	BLM CA, BLM NV	Woody Riparian	X	X	—	X	Yes, this species is primarily found at higher elevations but has been detected along the Colorado River corridor (Carpenter et al. 2021; NatureServe 2025i).
Long-legged myotis (*Myotis volans*)	BLM NV	Upland	—	—	—	—	No, this species is found in coniferous forests which will not be affected by any alternative (NatureServe 2025j).
Merriam's shrew (*Sorex merriami*)	BLM NV	Upland	—	—	—	—	No, this species inhabits upland grasslands and desertscrub which will not be affected by any alternative (NatureServe 2025k).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Mexican free-tailed bat (*Tadarida brasiliensis*)	BLM NV, CSC	Woody Riparian	X	X	X	X	Yes, this species is present at Lake Mead Recreation Area (Carpenter et al. 2021; NatureServe 2025l).
Mexican long-tongued bat (*Choeronycteris mexicana*)	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (BCI 2025a).
Pallid bat (*Antrozous pallidus*)	BLM NV, CSC	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NatureServe 2025m*).
Palm Springs pocket mouse (*Perognathus longimembris bangsi*)	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025n).
Palm Springs round-tailed ground squirrel (*Xerospermophilus tereticaudus chlorus*)	BLM CA	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025o).
Panamint kangaroo rat (*Dipodomys panamintus*)	BLM NV	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025p).
Pocketed freetail bat (*Nyctinomops femorosaccus*)	CSC	Woody Riparian	—	—	—	X	Yes, this species may utilize woody riparian habitats along the Little Colorado River to feed (ADW 2025*).
Silver-haired bat (*Lasionycteris noctivagans*)	BLM NV	Woody Riparian	X	X	X	X	Yes, this species has been documented in Lake Mead and along the Colorado River (Carpenter et al. 2021; NPSpecies 2011d).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Spotted bat (*Euderma maculatum*)	BLM AZ, BLM NV, BLM UT	Woody Riparian	X	X	X	X	Yes, this species has been identified along the Little Colorado River and occurs throughout the river corridor from Glen Canyon to Lake Mead (Carpenter et al. 2021; Luce and Keinath 2007).
Townsend's big-eared bat (*Corynorhinus townsendii*)	BLM AZ, BLM CA, BLM NV, BLM UT, LCR MSCP	Woody Riparian	X	X	X	X	Yes, the analysis area is within the range of this species (Carpenter et al. 2021; NPS 2020). This species uses woody riparian habitats, desert washes, and upland habitats (LCR MSCP 2018a).
Western red bat (*Lasiurus blossevillii*)	BLM NV, BLM UT, LCR MSCP	Woody Riparian	X	X	—	—	Yes, this species has been recorded in riparian habitats dominated by cottonwoods, oaks, sycamores, and walnuts, including riparian restoration sites along the lower Colorado River (Carpenter et al. 2021; Pierson et al. 2026).
Western small-footed myotis (*Myotis ciliolabrum*)	BLM CA, BLM NV	Woody Riparian	X	X	X	X	Yes, this species is present within Grand Canyon (Carpenter et al. 2021; NatureServe 2025q).
Western yellow bat (*Lasiurus xanthinus* = *Dasypterus xanthinus*)	LCR MSCP	Woody Riparian	—	—	X	X	Yes, the analysis area is within the range of this species (BCI 2025b).
Yuma hispid cotton rat (*Sigmodon hispidus eremicus*)	LCR MSCP	Marsh	—	—	—	X	Yes, this species is known to inhabit areas near the Colorado River in the analysis area (NatureServe 2025r).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Yuma puma (*Felis concolor browni*)	ASC, CSC	Woody Riparian	—	—	—	X	No, there are few to no breeding female lions, a lack of prey, and a lack of suitable habitat within the reported range of this population (Kucera 1998).
Yuma myotis (*Myotis yumanensis*)	BLM CA, BLM NV, CSC	Woody Riparian	X	X	X	X	Yes, this species is present throughout the Upper and Lower Colorado River basins (LCR MSCP 2018b; Carpenter et al. 2021; NatureServe 2025s).
Reptiles and Amphibians							
Arizona striped whiptail (*Aspidoscelis arizonae*)	BLM AZ	Upland	—	X	—	—	No, this species is isolated to a small region in southeastern Arizona and prefers upland habitats (Brennan et al. 2023a).
Arizona toad (*Anaxyrus microscaphus*)	BLM UT, BLM NV	Marsh	—	—	X	X (3)	Yes, this species may be present in the analysis area and lays eggs in calm, shallow areas along streams (NDOW 2025g).
Banded Gila monster (*Heloderma suspectum cinctum*)	BLM NV	Woody Riparian	—	—	X	X (2)	Yes, this species has been documented in the Colorado River Basin (Stebbins 2003).
Coast horned lizard (*Phrynosoma blainvillii*)	BLM CA	Upland	—	—	—	—	No, this species range is outside of areas affected by any alternative (Stebbins 2003).
Colorado River toad (*Bufo alvarius=Incilius alvarius*)	LCR MSCP	Woody Riparian	—	—	X	X	Yes, this species is often near permanent water but is also found near temporary water laying eggs in ponds or slow-moving streams (NatureServe 2025t).
Common chuckwalla (*Sauromalus ater*)	BLM NV	Upland	X	X	X	X (2,3)	No, this species is primarily found upland desertscrub habitat which will not be affected by any alternative (Brennan et al. 2023b).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Coronado skink (*Plestiodon skiltonianus interparietalis*)	BLM CA	Woody Riparian	—	—	—	—	No, this species' range is outside of areas affected by any alternative (CA Herps 2025a).
Couch's spadefoot (*Scaphiopus couchii*)	BLM CA	Marsh	—	—	X	X (3, 4)	Yes, this species has been documented in Lake Mead and along the Colorado River (iNaturalist 2025e).
Desert box turtle (*Terrapene ornata luteola*)	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (CA Herps 2025b).
Desert iguana (*Dipsosaurus dorsalis*)	BLM NV	Woody Riparian	—	X	X	X	Yes, this species has been observed at Lake Mead Recreation Area (NPS 2011).
Desert rosy boa (*Lichanura trivirgata gracia*)	CSC	Woody Riparian	—	—	—	X (7)	Yes, this species is attracted to intermittent and permanent water and its range overlaps with the analysis area (SWCHR 2023).
Mojave desert tortoise (*Gopherus agassizii*)	BLM NV, LCR MSCP, Threatened	Upland	—	—	X	X (2, 4)	Yes, the analysis area is within the range of this species (CA Herps 2025c).
Sonoran desert tortoise (*Gopherus morafkai*)	AZ SSS, CCA	Upland	—	—	X	X (4)	Yes, the habitat range for this species includes Lake Mead, Lake Mohave, and the eastern shore of the Colorado River (FWS 2025f).
Flat-tailed horned lizard (*Phrynosoma mcallii*)	BLM AZ, LCR MSCP	Upland	—	—	X	X (7)	Yes, the analysis area is within the range of this species (CDFW 2025b).
Foothill yellow-legged frog (south coast DPS) (*Rana boylii*)	BLM CA	Woody Riparian	—	—	—	—	No, this species range is outside of areas affected by any alternative (FWS 2025g).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Gilbert's skink (*Plestiodon gilberti rubricaudatus*)	BLM NV	Woody Riparian	—	—	—	X (2)	Yes, this species prefers to be near water and makes burrows which could be affected by inundation (Brennan et al. 2023c).
Goode's horned lizard (*Phrynosoma goodei*)	AZGFD	Upland	—	—	—	X (7)	Yes, this species is within the range of areas affected by alternative (AZGFD 2025ra).
Greater short-horned lizard (*Phrynosoma hernandesi*)	BLM NV	Upland	X	X	—	—	No, this species utilizes upland habitat which will not be affected by any alternative (NDOW 2025h).
Great Plains toad (*Anaxyrus cognatus*)	BLM NV	Marsh	—	—	—	X(2, 4, 5)	Yes, this species is within the range of areas affected and is known to use margins of reservoirs (NDOW 2025i).
Lowland burrowing treefrog (*Smilisca fodiens*)	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (AZGFD 2025b).
Lowland leopard frog (*Rana yavapaiensis*)	BLM AZ, BLM CA, LCR MSCP	Marsh	—	X	X	X	Yes, this species has a highly isolated population in one side canyon in western Grand Canyon (AZGFD 2025c).
Mohave fringe-toed lizard (*Uma scoparia*)	BLM AZ, BLM NV	Upland	—	—	—	X(4)	No, this species is primarily found in sand dunes and is not known to occur in riparian habitats (NDOW 2025j).
Northern leopard frog (*Lithobates [=Rana] pipens*)	BLM AZ, BLM NV	Marsh	X	—	—	—	Yes, although functionally extirpated along the river corridor from Glen to Mead (NDOW 2025k).
Northern Mexican gartersnake (*Thamnophis eques megalops*)	LCR MSCP, Threatened	Marsh, Woody Riparian	—	—	—	X(3)	Yes, this species may occur around Havasu National Wildlife Refuge and could be affected by alternative (FWS 2025h).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Relict leopard frog (*Rana onca*)	BLM AZ, BLM NV, LCR MSCP	Marsh	—	—	X	X (2)	Yes, this species has been observed above and below Hoover Dam (Rorabaugh and Brennan 2023).
Resplendent shovel-nosed snake (*Chionactis annulata*)	AZGFD	Upland	—	—	—	X (7)	Yes, the analysis area is within this species' range (CAHerps 2025d).
Ring-necked snake (*Diadophis punctatus*)	BLM NV	Woody Riparian	—	X	—	—	Yes, this species has been observed within Grand Canyon (NDOW 2025l).
Rosy boa (*Lichanura orcuttii*)	BLM NV	Woody Riparian	—	—	—	X(7)	Yes, the analysis area is within the range of this species (AZGFD 2022; CA Herps 2025e).
Sinaloan narrow-mouthed toad (are now known as the Mazatlan narrow-mouthed toad) (*Gastrophryne mazatlanensis*)	BLM AZ	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025u).
Sonoran green toad (*Bufo retiformis*)	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (NatureServe 2025v).
Two-striped gartersnake (*Thamnophis hammondii*)	BLM CA	Woody Riparian	—	—	—	—	No, this species range is outside of areas affected by any alternative (CA Herps 2025f).
Western pond turtle (*Emys marmorata*)	BLM CA	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternative (CA Herps 2025g).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Western spadefoot (*Spea hammondii*)	BLM CA	Upland	—	—	—	—	No, this species range is outside of areas affected by any alternative (CA Herps 2025h).
Western toad (*Anaxyrus boreas*)	BLM NV	Marsh	—	—	—	—	No, this species' range is outside of areas affected by any alternative (CA Herps 2025i).
Yuman desert fringe-toed lizard (*Uma rufopunctata*)	BLM AZ	Upland	—	—	—	—	No, this species' range is outside of areas affected by any alternative (CA Herps 2025j).
Invertebrates							
Amargosa tryonia (*Tryonia variegata*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the documented range of this species (FWS 2025i).
Amargosa miloderes weevil (*Miloderes amargosensis*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the documented range of this species (NatureServe 2025w).
Amargosa Valley darkling beetle (*Lariversius sp.*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the documented range of this species (NPS 2016).
Apache plume fairy bee (*Perdita fallugiae*)	BLM NV	Upland	—	—	—	—	No, this species is found throughout Clark County, NV in dry mountain washes where Apache Plume exists (Griswold et al. 2004).
Apache springsnail (*Pyrgulopsis arizonae*)	BLM AZ	Marsh	—	X	X	X	No, this species is only known from a few locations that will not be influenced by project operations (FWS 2025j).
Perdita bee (*Perdita stephanomeriae*)	BLM NV	Upland	—	X	X	—	Yes, this species has been documented near Lake Mead (NatureServe 2025x).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Ash Meadows alkali skipper (*Pseudocopaeodes eunus alinea*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025k).
Ash Meadows dune scorpion (*Paruroctonus arenicola arenicola*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025y).
Ash Meadows naucorid (*Ambrysus amargosus*)	BLM NV, Threatened	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025l).
Ash Meadows pebblesnail (*Pyrgulopsis erythropoma*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025m).
Atomic tarantula (*Aphonopelma atomicum*)	BLM NV	Upland	—	—	—	—	No, this species is limited to Death Valley National Park and Amargosa Desert (NatureServe 2025z).
Big-headed perdita (*Perdita cephalotes*)	BLM NV	Upland	X	—	—	X (1)	Yes, this species specializes on *Chrysothamnus spp.* which is present in the analysis area. This species is presumed to nest in the soil and could be affected by alternative (Griswold et al. 2004).
Carole's fritillary (*Argynnis coronis ssp. carolae*)	BLM NV	Upland	X	X	X	X	No, the analysis area is outside of the range of this species and does not contain suitable habitat (NatureServe 2025aa).
Crystal springsnail (*Pyrgulopsis crystalis*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025n).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Death Valley june beetle (*Polyphylla erratica*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025o).
Devils Hole warm spring riffle beetle (*Stenelmis calida calida*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025bb).
Distal-gland springsnail (*Pyrgulopsis nanus*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025p).
Dune honey ant (*Myrmecocystus arenarius*)	BLM NV	Upland	—	X	X	X	Yes, this species is found within the Mojave and Sonoran deserts and utilizes washes (NatureServe 2025cc).
Eastern desert snail (*Eremarionata rowelli*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is isolated to springs in the Amargosa River Basin (NatureServe 2025dd).
Elongate-gland springsnail (*Pyrgulopsis isolata*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025q).
Fairbanks springsnail (*Pyrgulopsis fairbanksensis*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is endemic to Fairbanks Spring in Ash Meadows, located within Amargosa Valley (FWS 2025r).
Gila tyronia (*Tryonia gilae*)	BLM AZ	Marsh	—	X	X	X	No, this species is only known from a few locations that will not be influenced by project operations (FWS 2025s).
Giuliani's dune scarab (*Pseudocotalpa giulianii*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025ee).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Grand wash springsnail (*Pyrgulopsis bacchus*)	BLM NV	Upland	—	X	X	X	No, this species is only found in a watershed feeding Lake Mead; this watershed will not be influenced by project operations (AZGFD 2025d).
Grated tryonia (*Tryonia clathrata*)	BLM NV	Woody Riparian	—	—	—	—	No, this species occurs in spring-fed habitats and there is no observational data of this species occurring south of Moapa, NV (FWS 2025t).
Gypsum booklouse (*Speleketor flocki*)	BLM NV	Upland	—	—	—	—	No, this species is only known to occur within Ash Medows, NV, Big Gypsum Valley, CO, and the Tucson Mountains, AZ (NatureServe 2025ff).
Interior tiger beetle (*Parvindela terricola continua*)	BLM NV	Marsh	—	—	—	—	Yes, this species is known to occur within Southern California along alkaline or saline soils and salt lake margins (NatureServe 2025gg).
Inyo Mountains blue (*Euphilotes bernardina inyomontana*)	BLM NV	Upland	—	—	—	—	No, this species is only known to occur within Inyo and eastern Kern Counties (Davenport 2018).
Kingman springsnail (*Pyrgulopsis conica*)	BLM AZ	Woody Riparian	—	X	X	X (2, 3, 4, 5)	Yes, this species is found in the Colorado River (AZGFD 2025e).
Knight's aegialian scarab (*Aegialia knighti*)	BLM NV	Upland	—	—	—	—	No, this species occurs in sandy substrates and records indicate presence within Moapa and north of Moapa, NV (NatureServe 2025hh).
Large aegialian scarab (*Aegialia magnifica*)	BLM NV	Upland	—	—	—	—	No, this species is only known to occur in Nye County, NV (NatureServe 2025ii).
Las Vegas fairy bee (*Perdita cracens*)	BLM NV	Upland	—	—	X	—	No, little is known about this species and its range (Griswold et al. 2004).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Leaf beetle sp. (*Trirhabda gurneyi*)	BLM NV	Upland	—	—	—	—	No, this species inhabits upland weedy fields and brushy areas (Iowa State University 2025).
MacNeill's sooty-winged skipper (*Hesperopsis gracielae*)	BLM NV, LCR MSCP	Upland	—	—	X	X (4, 5)	Yes, this species occurs along the Colorado River from southwest Utah through southern Nevada, western Arizona, and California (LCR MSCP 2017, 2018c; NatureServe 2025).
May beetle sp. (*Phyllophaga benwaneri*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is adapted to sand dune habitats (Warner 2021)
Median-gland springsnail (*Pyrgulopsis pisteri*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is found within thermal systems and spring-fed streams and has only been observed within Ash Meadows and Amargosa Valley (FWS 2025u).
Mercury miloderes weevil (*Miloderes mercuryensis*)	BLM NV	Upland	—	—	—	—	No, this species is limited to the Amargosa Valley, NV (NatureServe 2025jj).
Moapa fairy bee (*Perdita fulvescens*)	BLM NV	Upland	—	—	—	—	No, this species is endemic to the Moapa, NV area (Griswold et al. 2004).
Moapa mydas fly (*Rhaphiomidas moapa*)	BLM NV	Woody Riparian	—	—	—	—	No, this species has only been recorded in one wash in Clark County, NV (NatureServe 2025kk).
Moapa pebblesnail (*Pyrgulopsis avernalis*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is endemic to springs in Moapa Valley (FWS 2025v).
Moapa Valley pyrg (*Pyrgulopsis carinifera*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is endemic to springs in Moapa Valley (FWS 2025w).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Moapa warm spring riffle beetle (*Stenelmis moapa*)	BLM NV	Woody Riparian	—	—	—	—	No, this species prefers habitats with warm springs (83-96 deg F) and is endemic to the Moapa Valley (FWS 2025x).
Mojave gypsum bee (*Andrena balsamorhizae*)	BLM NV	Marsh	—	—	X	—	Yes, this species is associated with rare plant species in gypsum soils around Lake Mead and could be affected by inundation to full pool if vegetation expands into the lake during lower elevation years (NatureServe 2025ll).
Mojave Mountain fairy bee (*Perdita vicina*)	BLM NV	Woody Riparian	—	—	X	—	Yes, this species is endemic to Clark County, NV and is a specialist on Apache Plume which could be affected by inundation (NatureServe 2025mm).
Mojave poppy bee (*Perdita meconis*)	BLM NV	Upland	—	—	X	—	Yes, this species is associated with rare plant species in gypsum soils around Lake Mead and could be affected by inundation to full pool if vegetation expands into the lake during lower elevation years (Griswold et al. 2004).
Mojave twilight bee (*Perdita celadona*)	BLM NV	Upland	—	—	X	—	Yes, this species makes burrows which could be affected by full inundation (NatureServe 2025nn).
Monarch butterfly (*Danaus plexippus plexippus*)	BLM NV, Proposed Threatened	All	X	X	X	X (2, 3, 4, 5, 6, 7)	Yes, this species is present during migration and over wintering along the Little Colorado River. It has been documented in cottonwood-willow, and mesquite and marsh habitats (NatureServe 2025oo).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Nearctic riffle beetle (*Stenelmis occidentalis*)	BLM NV	Woody Riparian	—	—	—	—	No, this species has not been observed near the analysis area (iNaturalist 2025f).
Nevada admiral (*Limenitis weidemeyerii nevadae*)	BLM NV	Woody Riparian	—	—	—	—	No, the only known population of this subspecies is west of Las Vegas near Charleston Peak (NatureServe 2025pp).
Northern Mojave blue (*Euphilotes mojave virginensis*)	BLM NV	Upland	—	X	X	X	Yes, this species is associated with buckwheat which is present in the analysis area (NatureServe 2025qq).
Nye County army ant (*Neivamyrmex nyensis*)	BLM NV	Upland	—	X	—	—	No, verry little is known about this species (NatureServe 2025rr).
Nye County pyrg (*Pyrgulopsis licina*)	BLM NV	Upland	—	—	—	—	No, this species is endemic to Ash Meadows (NatureServe 2025ss).
Pahranagat naucorid bug (*Pelocoris biimpressus shoshone*)	BLM NV	Woody Riparin	—	—	—	—	No, the subspecies *shoshone* has not been observed near the Colorado River (NatureServe 2025tt).
Point of Rocks tryonia (*Tryonia elata*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species. Only known species locations are in springs near Nye and Clark County, west of Mercury, NV (FWS 2025y).
Prodigious fairy bee (*Perdita prodigiosa*)	BLM NV	Upland	—	—	—	—	No, the habitat for this species is unknown (NatureServe 2025uu).
Red-tailed blazing star bee (*Megandrena mentzeliae*)	BLM NV	Upland	—	—	X	—	Yes, this species is ground nesting and has been observed within the analysis area (iNaturalist 2025g).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Robber fly sp. (*Stackelberginia cerberus*)	BLM NV	Upland	—	—	—	—	No, this species has only been observed in the Amargosa desert (iNaturalist 2025h)
Sanchez pyrg (*Pyrgulopsis sanchezi*)	BLM NV	Woody Riparian	—	—	—	—	No, this species is endemic to the Amargosa River basin (NatureServe 2025vv).
Sin City scorpion (*Pseudouroctonus peccatum*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (Tate et al. 2013).
Sonoran talussnail (*Sonorella magdalenensis*)	BLM AZ	Upland	—	X	—	—	No, this species occurs in upland habitats and will not be affected by any alternative (NatureServe 2025ww).
Southwest Nevada pyrg (*Pyrgulopsis turbatrix*)	BLM NV	Woody Riparian	—	—	—	—	No, this species has not been observed within the analysis area (NatureServe 2025xx).
Southwest viceroy butterfly (*Limenitis archippus obsoleta*)	BLM NV	Woody Riparian	—	X	—	—	Yes, this species feeds on trees in the willow family which may be affected by alternative (NatureServe 2025yy).
Sportinggoods tryonia (*Tryonia angulata*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (FWS 2025z).
Spring Mountains dark blue early form (*Euphilotes ancilla purpura*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025zz).
Spring Mountains dark blue late form (*Euphilotes ancilla cryptica*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025aaa).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Spring Mountains forestfly (*Malenka murvoshi*)	BLM NV	Upland	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025bbb).
Spring Mountains sagebrush checkerspot (*Chlosyne acastus robusta*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (NatureServe 2025ccc).
Spring Mountains springsnail (*Pyrgulopsis deaconi*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (McKelvy et al. 2020).
Spring Mountains undescribed pyrg 1 (*Pyrgulopsis sp. 1*)	BLM NV	Woody Riparian	—	—	—	—	No, the analysis area is outside the range of this species (McKelvy et al. 2020).
Spurge-loving perdita (*Perdita euphorbiae*)	BLM NV	Upland	—	—	—	—	No, no known populations exist within the areas affected by any alternative (NatureServe 2025ddd).
Thorne's hairstreak (*Callophrys thornei*)	BLM CA	Woody Riparian	—	—	—	—	No, this species relies on Tecate cypress, which will not be affected by any alternative (NatureServe 2025eee).
Tiquilia fairy bee (*Perdita exusta*)	BLM NV	Woody Riparian	—	X	X	—	Yes, this species relies on *Tiquilia hispidissima*, which has been observed along the Colorado River (Griswold et al. 2004).
Two-tone fairy bee (*Perdita bipicta*)	BLM NV	Unkn	—	—	—	—	No, the habitat for this species is unknown habitat (Griswold et al. 2004).
Virgin River perdita (*Perdita crotonis caerula*)	BLM NV	Unkn	—	—	—	—	No, the analysis area is outside the range of this species (Griswold et al. 2004).

Common Name (Scientific Name)	Listing Status	Habitat	Lake Powell	Glen Canyon Dam to Lake Mead	Lake Mead	Hoover Dam to SIB	Potential Impact
Virgin River tiger beetle (*Eunota praetextata pallidofemora*)	BLM NV	Woody Riparian	—	—	X	—	No, this species has not been observed in the analysis area (iNaturalist 2025i).
Virgin River twilight bee (*Perdina vespertina*)	BLM NV	Upland	—	—	—	—	No, this species is found within sandy washes, dunes, and creosote dominated basins in the Mohave Desert (NatureServe 2025fff).

BLM = Bureau of Land Management; CA = California; NV = Nevada; CSC = California Species of Concern; LCR MSCP = Lower Colorado River Multi-Species Conservation Program; AZ = Arizona.

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Technical Appendix 11

Cultural Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
ADOT	Arizona Department of Transportation
APE	area of potential effect
ASPT	Arizona State Parks and Trails
BLM	Bureau of Land Management
CCS	Continued Current Strategies
CFR	Code of Federal Regulations
DEM	digital elevation model
DOE	Department of Energy
EOCY	end-of-calendar year
EOWY	end-of-water year
EPNG	El Paso Natural Gas Company
FWS	United States Fish and Wildlife Service
GCNP	Grand Canyon National Park
HFE	high-flow experiment
LADWP	Los Angeles Department of Water and Power
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LCRO	Lower Colorado River Office
MWD	Metropolitan Water District of Southern California
NHA	National Heritage Area
NHL	National Historic Landmark
NHPA	National Historic Preservation Act
NHT	National Historic Trail
NIB	Northerly International Boundary
NPS	National Park Service
NRA	National Recreation Area
NRHP	National Register of Historic Places
NVCRIS	Nevada Cultural Resources Inventory System

Reclamation	Bureau of Reclamation
SCE	Southern California Edison
SHPO	State Historic Preservation Officer
SIB	Southerly International Boundary
SWGC	Southwest Gas Corporation
TCP	traditional cultural place
THPO	Tribal Historic Preservation Officer
U.S.	United States
USGS	United States Geological Survey
WAPA	Western Area Power Administration
WY	water year

TA 11. Cultural Resources

TA 11.1 Affected Environment

Cultural resources are the physical evidence of past or present cultures, including archaeological sites, historic-era buildings and structures, objects, trails, landforms, and other places of traditional, cultural, or religious importance. Cultural resources can be human-made or natural features and are, for the most part, unique, finite, and nonrenewable.

Of the many laws, regulations, executive orders, and policies concerning cultural resources, the most pertinent to this project is Section 106 of the National Historic Preservation Act (NHPA; 54 United States [U.S.] Code 306108), as amended, and its implementing regulations (36 Code of Federal Regulations [CFR] 800). The NHPA and its implementing regulations require federal agencies to take into account the effects of their undertakings (federal undertakings or federally permitted or funded undertakings) on historic properties. Historic properties are defined as any district, site, building, structure, or object included in or eligible for inclusion in the National Register of Historic Places (NRHP); these include properties of traditional religious and cultural importance to an Indian tribe or Native Hawaiian organization that meet the NRHP criteria (36 CFR 800.16(l)(1)). As such, they are a subset of cultural resources.

Management and ownership of the land through which the Colorado River runs is multifaceted. Bureau of Reclamation (Reclamation) manages river water operations. In southern Utah, northern Arizona, and southeastern Nevada, the river runs through Grand Canyon National Park (GCNP), the Lake Mead National Recreation Area (NRA), and the Glen Canyon NRA, which are managed by the National Park Service (NPS). In western Arizona and eastern California south of Nevada, the river runs through Bureau of Land Management (BLM), Reclamation, U.S. Fish and Wildlife Service (FWS), state, tribal, municipal, and private lands.

Reclamation is consulting with the Arizona, California, Nevada, and Utah State Historic Preservation Officers (SHPOs), land managing agencies, affected tribes, and other consulting parties to develop a project-specific programmatic agreement under Section 106 of the NHPA and its implementing regulations (36 CFR 800.14). As part of the development of the programmatic agreement, Reclamation, the SHPOs, the land managing agencies, the affected tribes, and other consulting parties have defined the area of potential effect (APE). For this analysis, the NEPA study area coincides with the APE, which also mirrors the Class I search area.

The study area for the analysis runs from the northern extent of Lake Powell to the Southerly International Boundary (SIB), and consists of the Colorado River channel from bank to bank except from Glen Canyon Dam to Lake Mead, where it stretches from canyon rim to canyon rim, as well as a 0.5-mile buffer on either side of the riverbank or canyon rim. The study area coincides with the search area used for the Class I records search conducted for this analysis (Tremblay et al. 2024a,

2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi 2024). The study area covers a total of 2,735,066 acres in Arizona, California, Nevada, and Utah.

TA 11.1.1 Identification Efforts

A Class I cultural resources record search was conducted for the study area in Arizona, California, Nevada, and Utah (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi 2024). Data were collected on archaeological sites, built environment resources, historic-era trails, special designations (National Historic Landmarks [NHLs]), congressionally designated areas (National Heritage Areas [NHAs] and National Historic Trails [NHTs]), traditional cultural places (TCPs), and resources of traditional cultural and religious importance to Native American peoples. Data were provided by the NPS (GCNP, Glen Canyon NRA, Lake Mead NRA, and NPS-managed portions of Grand Canyon-Parashant National Monument [NM]), National and State Registers of Historic Places, NHL and state landmark records, SHPO records, and the NPS Heritage Documentation Programs of the Historic American Building Survey, the Historic American Engineering Record, and the Historic American Landscapes Survey archives. Additionally, historical maps and aerials were checked for all states.

In Arizona, data were obtained from state databases and sources, such as AZSITE, Arizona State Museum Archaeological Records Office, and Arizona Department of Transportation; the Forest Service (Kaibab National Forest); and records searches conducted at BLM field offices or data provided by the BLM (Arizona Strip District Office, including BLM-managed portions of Grand Canyon-Parashant NM, Kingman Field Office, Lake Havasu Field Office, and Yuma Field Office).

In California, data were obtained from the California Historical Resources Information System at three different Information Centers (South Coastal Information Center, South Central Coastal Information Center, and Eastern Information Center). Cultural resource data were also obtained from the California Points of Historical Interest list, the California Historical Landmarks list, the Archaeological Determinations of Eligibility list, and the California State Historic Resources Inventory list.

In Nevada, cultural resources were identified through the Nevada Cultural Resources Inventory System (NVCRIS), Southern Nevada Archaeological Archive, and BLM records. In Utah, Utah Division of State History's (now known as the Utah Historical Society) Sego database and Historic Utah Building database were searched.

Information on TCPs and resources of traditional and religious concern to Native American peoples were gathered through ethnographic research and data provided by Reclamation and NPS. Historic General Land Office and topographic maps were also checked for potential cultural resources. Data on sites on tribal lands was not collected for this effort. Data about ancestral sites located on tribal lands is sensitive and confidential. Reclamation concluded that data collected from state and federal sources would be sufficient to characterize the overall numbers and types of resources that may be affected.

The Class I records search shows that much of the study area has not been surveyed for cultural resources. This is particularly true in the vicinity of Lake Mead and less for Lake Powell, as neither

of these reservoirs were fully surveyed before inundation began behind Hoover Dam in 1934 and behind Glen Canyon Dam in 1963. Because survey coverage for both Lake Powell and Lake Mead is very low, there is high potential for additional yet-to-be identified (that is, undiscovered) sites to exist in the study area. The following discussion concerns only previously recorded archaeological sites and built environment resources, as well as built environment resources found on aerial photographs. Additional resources may be, and are likely to be, present in the areas not covered by previous surveys.

Data were compiled in August 2023, and the 2023 datasets were incorporated into the analysis. Additionally, the NPS provided updated archaeological site counts for Lake Powell and Lake Mead (including Grand Canyon-Parashant NM) in March 2026, which supplemented the August 2023 dataset for the reservoirs. Therefore, the site counts used in the analysis do not reflect later agency database updates in the study area outside the reservoirs.

TA 11.1.2 Section 106 of the National Historic Preservation Act and Tribal Consultation

Per Section 106 of the NHPA and its implementing regulations (36 CFR 800), Reclamation is consulting with the Arizona, California, Nevada, and Utah SHPOs; Tribal Historic Preservation Officers (THPOs); affected tribes without THPOs; and consulting parties regarding the effects of the undertaking on historic properties. Reclamation is developing a project-specific programmatic agreement, in consultation with the SHPOs, THPOs, tribes without THPOs, cooperating agencies, and other consulting parties per 36 CFR 800.14 to outline a process to resolve any adverse effect on historic properties from Reclamation's operation of the Glen Canyon and Hoover dams under the new operating guidelines for annual releases.

TA 11.1.3 Cultural Background

The Colorado River and its surrounding landscape holds significance for many peoples today and has for thousands of years. Indigenous peoples have a strong connection to the river, which plays an important role in their histories and lives. Indigenous peoples' relationship and kinship with the Colorado River is complex and is discussed further in the Tribal Resources (see **TA 13**, Tribal Resources). The following presentation of cultural resources data is from a Western viewpoint and Reclamation acknowledges that this is a partial picture and stems from the viewpoint of Western archaeologists and federal regulations largely promulgated by non-Indigenous peoples. For many Indigenous peoples, archaeological sites are sacred places inhabited in the past and today by ancestors.

Western archaeologists view the human history of the Colorado River and its surrounding landscape in terms of three general temporal components: precontact (including the Paleoindian, Archaic, and Formative cultural periods), ethnohistoric, and postcontact (historic-era). Indigenous concepts of time are also different from Western ideas. For example, the Zuni provided text describing the Zuni concept of time, beginning with their emergence in the Grand Canyon (see **TA 13**, Tribal Resources).

TA 11.1.4 Class I Results

Arizona

Overall, 870 cultural resource investigations (projects) have been conducted in the study area for an overall survey coverage of approximately 4 percent (Tremblay et al. 2024b). This number includes both the non-NPS and NPS datasets and accounts for duplicate records between the datasets. The Class I records search of non-NPS data sources showed that 363 projects have been conducted in the study area in Arizona; however, these projects only cover approximately 2 percent of the study area, and the majority of those projects are over 10 years old. Projects include block and linear surveys, data recovery, and monitoring projects associated with gas pipelines, fiber-optic lines, transmission lines, road and highway construction, mining operations, and numerous development projects, and land transfers. The Class I records search of NPS data sources demonstrated that 521 projects had been conducted resulting in coverage of approximately 3 percent of the study area. Like projects outside the parks, the projects consist of block and linear intensive archaeological surveys, monitoring, and data recovery treatments associated with recreational development, vegetation management, post-fire assessments, land and timber transfers, graffiti removal, and a number of "documentation as preservation" surveys.

California

Within the study area in California, 216 archaeological projects have been conducted (Eddy et al. 2024). Previously conducted projects include survey, data recovery, monitoring, literature reviews, and planning documents. Of the 216 previously conducted archaeological investigations, 161 were surface surveys, covering approximately 11 percent of the study area in California. Projects were conducted in support of a variety of projects including but not limited to transmission lines, water infrastructure, fiber optics installation, pipelines, residential and commercial development, highway projects, prescribed burns and fuel breaks, and agricultural projects.

Nevada

Within the Nevada study area, 605 archaeological projects have been conducted; 408 of the surveys are from the NPS dataset (Winslow et al. 2024). Most of these projects were surveys in support of improvements at Lake Mead NRA, other recreational projects, utility installation, and road improvements. Previous survey covers approximately 5 percent of the study area in Nevada.

Utah

In total, 135 previous survey projects have been conducted within the Utah study area covering 37 percent of the Utah study area (Eskenazi 2024). These surveys were conducted in support of research and improvements to facilities in the Glen Canyon NRA, road improvements, transmission lines, land exchanges, and movie sets.

Archaeological Sites

As discussed above, survey coverage of the study area is variable by state but is overall very low, ranging from 2 or 3 percent in Arizona, 5 percent in Nevada, 11 percent in California, and 37 percent in Utah. Because of the low coverage, the numbers of archaeological sites presented below do not reflect the total number of sites in the study area and are likely only a small fraction of the sites that are present. However, the sites that have been recorded give an overall picture of resources

that may be found in the study area and are used in the analysis as a representative dataset for what may be present in unsurveyed areas.

Arizona

A total of 4,246 archaeological sites were identified in the study area in Arizona based on the 2023 Class I records search (Tremblay et al. 2024b). This number includes both non-NPS and NPS data accounting for duplicates between the two datasets. **Table TA 11-1** summarizes the NRHP status and temporal components of all archaeological sites within the study area in Arizona.

Table TA 11-1
Summary Counts of Previously Recorded Sites in the Study Area in Arizona

		Overall Study Area
Count (Sites)		**4,246**
NRHP	NRHP Listed	13
	Determined Eligible	3,059
	Recommended Eligible	41
	Determined Ineligible	144
	Recommended Ineligible	92
	Unevaluated	897
Temporal Component	Precontact	3,231
	Ethnohistoric	50
	Postcontact	458
	Multicomponent	282
	Unknown	225

Source: Tremblay et al. 2024b
Note: The information presented in this table incorporates NPS and non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Non-NPS Dataset

The 2023 record search of non-NPS data identified 1,246 archaeological sites in the study area (Tremblay et al. 2024b). Seventeen sites in the study area are listed in the NRHP; 12 of the 17 listed sites are within the Ripley Intaglio Complex Historic District. Of the 1,246 sites, 345 are determined and recommended eligible for the NRHP and 126 are determined or recommended not eligible. The remaining 758 sites are unevaluated for the NRHP or of unknown NRHP status.

Of the 1,246 sites, 985 are precontact sites, 107 are postcontact (historic-era) sites, two are ethnohistoric sites, and 56 are multicomponent sites (i.e., used during more than one temporal period). The temporal affiliations of the remaining 96 sites are unknown. Precontact sites or site components could be attributed to the Paleoindian and Archaic period cultures, as well as the Basketmaker and Ancestral Puebloan cultures. Ethnohistoric sites or site components are affiliated with Mohave, Southern Paiute, Hopi, Diné (Navajo), and indeterminate Indigenous peoples. Postcontact (historic-era) component sites are overwhelmingly associated with Euro-American

culture; however, a few historic-era sites are attributed to Havasupai, Mohave, Diné (Navajo), Pai, Southern Paiute, Ute, and indeterminate Indigenous peoples.

Table TA 11-2 presents a summary of site function for sites in the non-NPS dataset. For precontact sites and site components, limited activity artifact scatters were the most abundant, but both long- and short-term habitation sites, resource procurement and processing sites, lithic reduction sites, and petroglyph/pictograph sites were well-represented. Although in smaller numbers, agricultural and water management sites, storage sites or caches, ceremonial or special-use sites, and trails were also present. Site functions for ethnohistoric sites or site components are similar to those from precontact component sites and include limited activity sites, an agricultural site, temporary camps, long-term habitations, resource processing sites, special-use sites, and a trail. The most common function of historic sites and site components is waste management (refuse piles). Other functions include mining, ranching, agriculture, permanent habitations, temporary camps, public utilities, and water management, as well as numerous transportation features, including roads, trails, and ferry crossings.

Table TA 11-2
Summary of Site Functions within the Study Area in Arizona (Non-NPS Data Only) by Temporal Component

Site Function	Count	Temporal Component		
		Precontact	Ethnohistoric	Postcontact
Limited Activity (Artifact Scatters)	236	233	3	0
Habitation	206	186	2	18
Temporary Habitations/Camps	155	133	2	20
Resource Procurement/Processing	167	163	2	2
Agriculture	52	47	1	4
Lithic Reduction	113	113	0	0
Storage/Cache	36	35	0	1
Ceremonial/Religious/Special Use	28	25	0	3
Petroglyphs/Pictographs	161	150	2	9
Water Management	15	12	0	3
Waste Management (Refuse Piles)	24	0	0	24
Transportation (Roads/Trails/Ferries/etc.)	16	1	0	15
Utility	2	0	0	2
Livestock/Ranching	11	0	0	11
Mining	18	0	0	18
Industrial	2	0	0	2
Government	5	0	0	5

Site Function	Count	Temporal Component		
		Precontact	Ethnohistoric	Postcontact
Military	2	0	0	2
Commerce	4	0	0	4
Unknown	22	16	0	6

Source: Tremblay et al. 2024b
Notes:

- Some sites have multiple functions identified for individual components, such that total site function counts in this table will exceed the total number of individual sites/components within each temporal category.
- The table does not include sites/components where temporal affiliations were not available. The information presented in this table incorporates non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current databases.

NPS Dataset

As stated above, data provided by the NPS will be presented separately where applicable. This means that some sites are found in both the non-NPS and NPS databases. Counts of NPS sites presented below are based on the complete NPS dataset consisting of data acquired in August 2023 and updated in March 2026. Duplicate sites are accounted for above in **Table TA 11-1**.

A total of 4,135 previously recorded archaeological sites are found in the NPS dataset for the study area based on the March 2026 update. Sixteen sites are listed in the NRHP, another 3,315 sites have been determined or recommended eligible, 80 sites have been determined or recommended not eligible, and 678 are unevaluated. There are 46 sites in the Glen Canyon NRA dataset where no NRHP eligibility was given. See **Table TA 11-3** for eligibility by park unit.

Table TA 11-3
Summary Counts of Previously Recorded Sites for NPS Data by Park Unit in Arizona

		Park Unit			Total
		GCNP	Lake Mead NRA	Glen Canyon NRA	
Total Count (Sites)		**3,175**	**790**	**170**	**4,135**
NRHP	NRHP Listed	3	1	12	**16**
	Determined Eligible	3,097	9	14	**3,120**
	Recommended Eligible	7	157	31	**195**
	Determined Ineligible	20	6	7	**33**
	Recommended Ineligible	6	30	11	**47**
	Unevaluated	42	587	49	**678**
	Unknown/No Status	0	0	46	**46**

Source: NPS (including GCNP, Glen Canyon NRA, and Lake Mead NRA staff)
Notes: The information presented in this table incorporates NPS data acquired in March 2026 from current park databases; therefore, the number of sites and/or their corresponding information do not reflect information presented in other tables that rely on the August 2023 Class I records search. Total site counts for Lake Mead NRA also include sites from the NPS-managed portions of Grand Canyon-Parashant NM in Arizona.

Precontact sites or site components from the NPS dataset are attributed to time periods that archaeologists identify as Paleoindian and Archaic period, Basketmaker, Ancestral Puebloan, Cohonina, Patayan, and Cerbat cultures and peoples (**Table TA 11-4**). Ancestral Puebloan sites are most common, and indeterminate Indigenous peoples are second-most common. Ethnohistoric sites or site components are attributed to the Havasupai, Hopi, Diné (Navajo), Pai, and Southern Paiute peoples. For postcontact (historic-era) sites or site components, sites attributed to Euro-American sites are most common; however, several sites are attributed to Havasupai, Hopi, Diné (Navajo), Pai, Southern Paiute peoples, or unspecified Indigenous native cultures.

Table TA 11-4
Summary of Cultural Affiliations in NPS Dataset by Park Unit in Arizona

	Park Unit			Total
	GCNP	Lake Mead NRA	Glen Canyon NRA	
Cultural Affiliation – Precontact				
Paleoindian	2	1	1	4
Archaic	12	0	1	13
Basketmaker	17	0	1	18
Ancestral Puebloan	1,346	8	33	1,387
Patayan	2	13	0	15
Cohonina	302	0	0	302
Cerbat	35	0	0	35
Indigenous Native Culture	759	71	38	868
Unknown	0	2	0	2
Cultural Affiliation – Ethnohistoric				
Pai	29	0	0	29
Southern Paiute	64	0	0	64
Hopi	20	0	0	20
Diné (Navajo)	7	0	0	7
Havasupai	4	0	0	4
Indigenous Native Culture	10	0	0	10
Cultural Affiliation – Postcontact				
Euro-American	401	28	12	441
Diné (Navajo)	24	0	3	27
Havasupai	16	0	0	16
Southern Paiute	8	1	1	10
Pai	2	0	0	2
Hopi	6	0	0	6
Indigenous Native Culture	38	3	0	41
Unknown	7	0	0	7

Source: Tremblay et al. 2024b
Note: The information presented in this table incorporates NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current park unit databases.

Precontact site functions include agricultural, ceremonial/religious/special use, habitation, temporary habitation/camp, limited activity, lithic reduction, resource procurement/processing, petroglyphs/pictographs, storage/cache, transportation (trails), and water management sites (**Table TA 11-5**). Among these, longer-term habitations, resource processing sites, and temporary habitations were the most common. Ethnohistoric site and site component functions are similar to those of precontact sites and include agriculture, habitation, temporary habitation/camp, ceremonial/religious/special use, limited activity, lithic reduction, resources procurement/processing, storage/cache, and petroglyphs/pictographs. Historic site or site component functions consist of temporary habitations/camps, mining, ranching, agriculture, utilities, and water management, as well as numerous sites associated with transportation, such as ferry crossings.

Table TA 11-5
Summary of Site Functions for NPS Dataset by Park Unit in Arizona

	Park Unit			Total
	GCNP	Lake Mead NRA	Glen Canyon NRA	
Site Function – Precontact				
Limited Activity (Artifact Scatters)	231	14	24	**269**
Habitation	709	23	3	**735**
Temporary Habitations/Camps	465	21	6	**492**
Resource Procurement/Processing	535	9	4	**548**
Agriculture	123	0	0	**123**
Lithic Reduction	108	16	13	**137**
Storage/Cache	128	0	1	**129**
Ceremonial/Religious/Special Use	82	1	1	**84**
Petroglyphs/Pictographs	98	6	21	**125**
Water Management	4	1	0	**5**
Unknown	56	1	7	**64**
Site Function – Ethnohistoric				
Limited Activity (Artifact Scatters)	4	0	0	**4**
Habitation	9	0	0	**9**
Temporary Habitations/Camps	35	0	0	**35**
Resource Procurement/Processing	48	0	0	**48**
Agriculture	3	0	0	**3**
Lithic Reduction	1	0	0	**1**
Storage/Cache	4	0	0	**4**
Ceremonial/Religious/Special Use	5	0	0	**5**
Petroglyphs/Pictographs	17	0	0	**17**
Water Management	1	0	0	**1**
Site Function – Postcontact				
Limited Activity (Artifact Scatters)	85	2	0	**87**
Habitation	48	4	2	**54**

	Park Unit			Total
	GCNP	Lake Mead NRA	Glen Canyon NRA	
Temporary Habitations/Camps	122	2	1	**125**
Resource Procurement/Processing	33	0	1	**34**
Agriculture	5	2	0	**7**
Lithic Reduction	1	0	0	**1**
Storage/Cache	7	0	0	**7**
Ceremonial/Religious/Special Use	38	0	2	**40**
Petroglyphs/Pictographs	12	3	8	**23**
Water Management	4	0	1	**5**
Waste Management (Refuse Piles)	18	3	1	**22**
Transportation (Roads/Trails/Ferries/etc.)	27	5	2	**34**
Utility	2	2	0	**4**
Livestock/Ranching	32	1	0	**33**
Mining	39	4	1	**44**
Government	0	2	0	**2**
Unknown	23	3	2	**28**

Source: Tremblay et al. 2024b
Note: The information presented in this table incorporates NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current park unit databases.

California

A total of 551 previously recorded archaeological resources were identified within the study area in California as a result of the Class I records search. Of the 551 previously recorded archaeological resources, 493 are classified as archaeological sites, and 58 are classified as isolated occurrences. For the previously recorded archaeological resources (both sites and isolated occurrences), 4 are listed in the NRHP, 22 are recommended or determined eligible for the NRHP, 13 are recommended or determined ineligible or non-significant, and 512 are unevaluated or of unknown NRHP status. Of the 493 archaeological sites, 372 are precontact sites, 78 are postcontact (historic-era) sites, 31 are multicomponent sites with both precontact and postcontact (historic-era) resources, one is a multicomponent site with both precontact and ethnohistoric resources, and 11 sites are unknown.

Site or site component functions within the study area are shown in **Table TA 11-6**. The most common function is lithic reduction followed by transportation (trail). Other common functions include habitation; waste management; ceremonial, religious, and special use; and camps. Some sites or site components are of indeterminate function and are listed in **Table TA 11-6** according to their site type (i.e., potter scatter or rock feature).

Table TA 11-6
Summary of Site or Site Component Functions within the Study Area in California

Function	Numbers of Sites or Site Components
Limited Activity	4
Habitation	71
Camp	26
Resource Procurement/Processing	9
Road	3
Lithic Reduction	264
Storage/Cache	1
Ceremonial, Religious, and Special Use	43
Rock Art	0
Waste Management	48
Water Management	5
Transportation	0
Utility	2
Livestock/Ranching	0
Industrial-Mining	3
Industrial-Other	0
Government	1
Rock Feature	16
Pottery Scatter	38
Trail	98
Quarry	5
Other	9

Source: Eddy et al. 2024
Note: The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Nevada

In the Nevada study area, 664 archaeological sites were identified in the non-NPS and NPS datasets (99 non-NPS [NVCRIS only] and 565 NPS) based on the Class I records search. Four sites are listed in the NRHP (including the B-29 Heavy Bomber Superfortress and the Pueblo Grande de Nevada: Main Ridge Locality); all are in the Lake Mead NRA. Additionally, a total of 29 sites are eligible or contributing for the NRHP (13 non-NPS and 16 NPS), including the St. Thomas historic townsite (ca. 1865). Fifty-five are ineligible (18 non-NPS and 37 NPS), and the remaining 576 resources are either unevaluated or unknown (68 non-NPS and 508 NPS). See **Table TA 11-7** and **Table TA 11-8** for non-NPS and NPS site eligibility, respectively.

Table TA 11-7
Summary Counts of Previously Recorded Sites for Non-NPS Data in Nevada

		Total
Total Count (Sites)		**99**
NRHP	NRHP Listed	**0**
	Eligible	**13**
	Ineligible	**18**
	Unevaluated/Unknown	**68**

Source: Winslow et al. 2024
Note: The information presented in this table incorporates non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Table TA 11-8
Summary Counts of Previously Recorded Sites for NPS Data in Nevada

		Total
Total Count (Sites)		**565**
NRHP	NRHP Listed	**4**
	Determined Eligible	**4**
	Recommended Eligible	**12**
	Determined Ineligible	**5**
	Recommended Ineligible	**32**
	Unevaluated	**508**

Source: NPS (Lake Mead NRA staff)
Notes: The information presented in this table incorporates NPS data acquired in March 2026 from current park databases; therefore, the number of sites and/or their corresponding information do not reflect information presented in other tables that rely on the August 2023 Class I records search. Total site counts presented here include both Lake Mead NRA and NPS-managed portions of Grand Canyon-Parashant NM in Nevada.

Precontact sites include habitation sites, rock shelters, campsites, artifact scatters, tool stone procurement localities, and rock features. Euro-American sites include roads, utility lines, house foundations, mines, recreation facilities, and sites associated with the construction and operation of Hoover and Davis Dams (**Table TA 11-9**).

Table TA 11-9
Summary of Site or Site Component Functions within the Study Area in Nevada

Function	Numbers of Sites or Site Components (NPS Data)	Numbers of Sites or Site Components (non-NPS Data)	Total
Habitation	40	47	87
Lithic Reduction	12	50	62
Lithic Procurement and Testing	1	20	21
Military	1	0	1
Mining	8	3	11
Ranching	0	1	1
Recreation	2	2	4
Resource Processing	0	4	4
Temporary Habitation	0	15	15
Town	1	0	1
Transportation	2	7	9
Unknown/Other	199	51	250
Utility	2	3	5
Waste Management	0	5	5
Water Management	6	31	37

Data source: Winslow et al. 2024
Note: The information presented in this table incorporates NPS and non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Utah

The Class I records search identified 1,384 sites (366 non-NPS and 1,018 NPS) within the Utah study area. Of the 1,384 sites, 2 are listed in the NRHP (non-NPS), 194 are eligible for the NRHP (56 non-NPS and 138 NPS), 143 are not eligible (20 non-NPS and 123 NPS), and 1,045 are unevaluated, undetermined, or have an unknown NRHP eligibility status (288 non-NPS and 757 NPS). See **Table TA 11-10** and **Table TA 11-11** for non-NPS and NPS site eligibility, respectively.

Table TA 11-10
Summary Counts of Previously Recorded Sites for Non-NPS Data in Utah

		Total
Total Count (Sites)		**366**
NRHP	NRHP Listed	**2**
	Eligible	**56**
	Ineligible	**20**
	Unevaluated/Unknown	**288**

Source: Eskenazi 2024
Note: The information presented in this table incorporates non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Table TA 11-11
Summary Counts of Previously Recorded Sites for NPS Data in Utah

		Total
Total Count (Sites)		**1,018**
NRHP	NRHP Listed	**0**
	Determined Eligible	**52**
	Recommended Eligible	**86**
	Determined Ineligible	**64**
	Recommended Ineligible	**59**
	Unevaluated	**512**
	Unknown/No Status	**245**

Data source: Glen Canyon NRA staff
Note: The information presented in this table incorporates NPS data acquired in March 2026 from current park databases; therefore, the number of sites and/or their corresponding information do not reflect information presented in other tables that rely on the August 2023 Class I records search.

Precontact sites and site components functioned as task-specific sites, domestic sites, unknown or other sites, transportation and communication sites, and special-use sites (**Table TA 11-12**). The postcontact (historic-era) sites and site components are associated with agriculture and subsistence, domestic use, industry, special-use sites, task-specific sites, transportation and communication, and unknown or other.

Table TA 11-12
Summary of Site or Site Component Functions within the Utah Study Area in Utah

Function	Numbers of Sites or Site Components (NPS Data)	Numbers of Sites or Site Components (non-NPS Data)	Total
Agriculture	0	8	8
Ceremonial, Religious, and Special Use	5	4	9
Communication	0	1	1
Defensive	1	0	1
Habitation	148	3	227
Limited Activity	38	96	134
Lithic Reduction	31	101	132
Mining	2	3	5
Ranching	8	2	10
Recreation	0	2	2
Resource Procurement/Processing	20	34	54
Rock Art	41	49	60
Storage	13	22	35

Function	Numbers of Sites or Site Components (NPS Data)	Numbers of Sites or Site Components (non-NPS Data)	Total
Temporary Habitation	62	127	189
Transportation	10	9	19
Unknown	8	47	55

Source: Eskenazi 2024

Note: The information presented in this table incorporates NPS and non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Built Environment Resources

Built environment resources are those human-made and/or intentionally modified components of our world that are shaped by the way we live, work, and play. For the purposes of this analysis, this includes buildings, structures, sites, objects, and districts that are historic in age (at least 50 years old since first constructed) and retain their basic structural elements, configurations, alignments, or patterns of organization (i.e., that are not in ruins and thus categorized as archaeological resources).

It is important to note that the state-specific lists of built environment resources discussed in this section do not include every individual resource or property type of historic age and, collectively, are not intended to represent a comprehensive inventory within the overall study area. Each state has different requirements when it comes to documenting built environment resources, as some state agencies manage such records in continuously maintained databases, while others do not. Arizona does not have a process to track built environment surveys conducted within the state, and at present, such resources are not assigned to any type of unique identifier like archaeological sites. California allocates project numbers to cultural resource investigations and assigns primary numbers to all cultural resources documented during those inventories, but the state's database system (California Historical Resources Information System) does not distinguish between archaeological and built environment (architectural) surveys and/or resources. Nevada maintains its own statewide inventory database where both archaeological and built environment inventories are registered by NVCRIS number and resources documented under the latter are currently assigned state-specific built environment numbers. Lastly, Utah manages information pertaining to previously recorded built environment resources (The HUB) where individual property record numbers are assigned.

Because Arizona, California, Nevada, and Utah each approach the management of built environment resource data in various ways, the types of information presented in this section are specific to each of the four states in the study area. For Arizona, built environment resources have not been documented consistently in the past, and currently, there is no systematic tracking or database managed for these resources. For this reason, the only sources of data that were readily available for historic-era built environment resources in Arizona were the NRHP and Arizona Register of Historic Places; lists encompassing designated NHLs, NHAs, and NHTs; NPS Heritage Documentation Programs (Historic American Building Survey, Historic American Engineering Record, and Historic American Landscapes Survey) databases; and historical aerial imagery. Because of this, only the most important built environment resources (as demonstrated by research) associated with the historic setting of the study area are included for analysis.

The datasets acquired from federal and state agencies were also examined to identify any additional properties that qualified as built environment resources, which were then culled from the archaeological site data; none of the datasets provided included information pertaining to NRHP-ineligible and/or unevaluated built environment resources. For California, all documented cultural resources are assigned a state-specific primary number and built environment resources documented in the study area were identified by their primary numbers from the comprehensive datasets obtained from the California Historical Resources Information System and other registers and lists. Conversely, because Nevada and Utah have (at least to some degree) state-maintained databases for built environment resources, those that are eligible, ineligible, and unevaluated for the NRHP are considered for analysis; however, this is limited to only those resources that have officially been assigned state resource numbers.

Additional details pertaining to identification efforts performed for resources in Arizona, California, Nevada, and Utah are presented in the data-gathering methods summaries in each state-specific volume (Tremblay et al. 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi 2024).

Finally, there is a substantial degree of overlap between designations, particularly involving NHLs and NRHP-listed historic properties, because NHLs are also listed in the NRHP when designated, if they have not been already. For this reason, where historic properties were listed in the NRHP before they were later designated as NHLs (in some cases, many years later), they are included for analysis as NRHP-listed built environment resources and NHLs. NHLs in the study area are discussed in a separate section below (see NHLs, NHAs, and NHTs).

Arizona

In all, a total of 49 previously evaluated built environment resources were identified as part of the Class I records search in the Arizona portion of the study area (Tremblay et al. 2024b). Of these, 43 are NRHP-listed (non-NHL) historic properties (8 districts, 26 buildings, 6 structures, 1 object, and 2 sites) and 6 are NRHP-eligible historic properties (all districts). **Table TA 11-13** provides a summary of NRHP-listed and NRHP-eligible built environment resources identified in the Arizona study area.

Table TA 11-13
NRHP-Listed and NRHP-Eligible Historic Properties in the Study Area in Arizona

DISTRICTS					
Name[a]	**NRHP Status**	**Year**	**Eligibility Criteria**	**Jurisdiction/ Ownership[b]**	**Administering Agency**
Lee's Ferry and Lonely Dell Ranch	Listed	1976, 1978 1997 (combined)	A, C	NPS	Glen Canyon NRA
*North Rim Entrance Road Corridor	Eligible	2011	A, C	NPS	GCNP
*Grand Canyon Inn and Campground	Listed	1982	A, C	NPS	GCNP

DISTRICTS

Name[a]	NRHP Status	Year	Eligibility Criteria	Jurisdiction/ Ownership[b]	Administering Agency
*Grand Canyon North Rim Headquarters	Listed	1982	A, C	NPS	GCNP
*El Tovar Stables	Listed	1974	A	NPS	GCNP
*Grand Canyon National Park Trail System	Eligible	N/A	A	NPS	GCNP
*Transcanyon Water Distribution Pipeline (including Silver Bridge)	Eligible	2016	A, C	NPS	GCNP
*Cross Canyon Corridor	Eligible	2015	A, C	NPS	GCNP
*Grand Canyon Railway	Listed	2000	A	NPS, U.S. Forest Service, Private	GCNP, Kaibab National Forest (federal lands only)
*Horace M. Albright Training Center	Listed	2013	A, C	NPS	GCNP
Temple Bar Developed Area	Eligible	2020	A	NPS	Lake Mead NRA
Katherine's Landing Developed Area	Eligible	2021	A	NPS	Lake Mead NRA
Parker Dam	Eligible	N/A	A, C	Reclamation	Lower Colorado River Office (LCRO)
Brinley Avenue	Listed	1982	A, C	Municipal, Private	City of Yuma (city lands only)
Yuma Main Street	Listed	1994	A	Municipal, Private	City of Yuma (city lands only)

BUILDINGS

Name[a]	NRHP Status	Year	Eligibility Criteria	Jurisdiction/ Ownership[b]	Administering Agency
*Buckey O'Neill Cabin	Listed	1975	A	NPS	GCNP
*Ranger's Dormitory	Listed	1975	A, C	NPS	GCNP
*Superintendent's Residence (First Administration Building)	Listed	1974	A	NPS	GCNP
San Carlos Hotel	Listed	1984	C	Private	N/A
Yuma County Courthouse	Listed	1982	A, C	County	Yuma County

BUILDINGS

Name[a]	NRHP Status	Year	Eligibility Criteria	Jurisdiction/ Ownership[b]	Administering Agency
Yuma Main Post Office	Listed	1985	A, C	Private	N/A
Cactus Press-Plaza Paint Building	Listed	1987	C	Private	N/A
Pauley Apartments	Listed	1982	C	Private	N/A
Methodist Parsonage	Listed	1982	A	Private	N/A
Methodist Episcopal Church	Listed	1982	A, C	Private	N/A
Masonic Temple	Listed	1984	C	Private	N/A
Hotel del Ming	Listed	1982	A, C	Private	N/A
Lee Hotel	Listed	1984	C	Private	N/A
Old Yuma City Hall	Listed	1982	A, C	Municipal	City of Yuma
Dressing Apartments	Listed	1982	C	Private	N/A
Power Apartments	Listed	1982	C	Private	N/A
Named private residences (n=10)	Listed	1982	B and/or C	Private	N/A

STRUCTURES

Name[a]	NRHP Status	Year	Eligibility Criteria	Jurisdiction/ Ownership[b]	Administering Agency
*Navajo Steel Arch Highway Bridge (Navajo Bridge)	Listed	1981	A, C	ADOT	ADOT
*Trans-Canyon Telephone Line	Listed	1986	A, C	NPS	GCNP
Old Trails Bridge (Topock Bridge)	Listed	1988	A, C	FWS, Private	FWS Southwest Region, EPNG
Historic U.S. Route 66 in Arizona	Listed	1989	A, C	FWS, State, County	FWS Southwest Region, ADOT, Mohave County
Ocean-to-Ocean Highway Bridge	Listed	1979	A, C	County	Yuma County
Southern Pacific Passenger Coach Car	Listed	2000	A, C	State	ASPT

SITES					
Name[a]	**NRHP Status**	**Year**	**Eligibility Criteria**	**Jurisdiction/ Ownership[b]**	**Administering Agency**
*Grand Canyon Pioneer Cemetery	Listed	1975	A, C	NPS	GCNP
Hardyville Pioneer Cemetery	Listed	2001	A	Municipal	City of Bullhead City
OBJECTS					
Name[a]	**NRHP Status**	**Year**	**Eligibility Criteria**	**Jurisdiction/ Ownership[b]**	**Administering Agency**
Blaisdell Slow Sand Filter Washing Machine	Listed	1979	A	Municipal	City of Yuma

Source: Tremblay et al. 2024b

Notes:

- Resources are listed in order from north to south by type (district, building, structure, site, object).
- The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.
- The Grand Canyon Inn and Campground and the Grand Canyon North Rim Headquarters historic districts are on the North Rim within GCNP, which recently suffered extensive damage from the 2025 Dragon Bravo Fire; therefore, the NRHP status for district components may have changed as a result of wildfire impacts. The Buckey O'Neill Cabin, Ranger's Dormitory, and Superintendent's Residence (First Administration Building) also contribute to the Grand Canyon Village NHL. The Grand Canyon Pioneer Cemetery is listed as part of the Grand Canyon Village Historic District but is not part of the Grand Canyon Village NHL. Parker Dam has not been evaluated as a district in Arizona but was subject to a preliminary assessment in California in 1997, concluding the dam and its components likely qualified as an NRHP-eligible historic district; a formal NRHP nomination is currently in progress for listing.

[a] Properties marked with an asterisk (*) are resources in the study area (or portions thereof in terms of linear resources like trails) that are spatially separated from the river corridor because of substantial vertical distance and/or intervening canyon terrain (by several thousand feet in elevation in some instances).

[b] Jurisdiction and ownership are given only for the study area, as follows: ADOT = Arizona Department of Transportation; EPNG = El Paso Natural Gas Company; ASPT = Arizona State Parks and Trails; and FWS.

Additionally, 16 unevaluated but notable built environment resources (five districts, one building, nine structures, one site) were also identified as important resources that may be eligible for the NRHP based on extensive research. **Table TA 11-14** summarizes these resources identified in the Arizona portion of the study area.

Table TA 11-14
Unevaluated But Notable Built Environment Resources in the Study Area in Arizona Listed from North to South

Name[a]	Property Type	Location/Vicinity[b]
Glen Canyon Dam	District	Glen Canyon NRA
*Glen Canyon Dam Bridge	Structure	Glen Canyon NRA
*Greenland Lake Salt Cabin	Building	GCNP

Name[a]	Property Type	Location/Vicinity[b]
Black Suspension Bridge (Kaibab Suspension Bridge)	Structure	GCNP
Davis Dam	District	Laguna
London Bridge	Structure	Lake Havasu City
Ehrenberg Pioneer Cemetery	Site	Ehrenberg
Palo Verde Diversion Dam	Structure	Yuma
Yuma Levee System (Yuma Project)	District	Yuma
Fisher's Landing	District	Yuma
Imperial Dam	Structure	Yuma
Gila Project	District	Yuma
Laguna Dam	Structure	Yuma
Southern Pacific Railroad[c]	Structure	Yuma
Southern Pacific Railroad Bridge (Colorado River)[c]	Structure	Yuma
Morelos Dam	Structure	Northerly International Boundary

Source: Tremblay et al. 2024b

Note: The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

[a] Properties marked with an asterisk (*) are resources in the study area (or portions thereof in terms of linear resources) that are spatially separated from the river corridor because of substantial vertical distance and/or intervening canyon terrain (by several thousand feet in elevation in some instances).

[b] Location and vicinity do not imply jurisdiction, ownership, or administrative responsibilities.

[c] The Southern Pacific Railroad has been recorded in other locations in Arizona, but the route as aligned through Yuma has not yet been documented and/or evaluated for the NRHP, nor has the Southern Pacific Railroad Bridge across the river.

California

A total of nine built environment investigations have been conducted within the California portion of the study area based on the Class I records search, which involved inventory and evaluation for components of the All-American Canal, the Imperial Dam, the Imperial Irrigation District, land ports of entry, and masonry arch bridges. In all, 63 historic-era built environment properties were identified from archival records searches, including three districts (Picacho Squatters Settlement District, Topock Compressor Station District, and Parker Dam), a regional park (Moabi Regional Park), and various buildings, structures, roads, and transmission lines (Eddy et al. 2024). **Table TA 11-15** summarizes the general categories of built environment resources (based on function and/or use) established for the literature review.

Table TA 11-15
Built Environment Resource Categories in the Study Area in California

Category	Number of Resources
Bridge	3
Building	12
District	3
Historic/Survey Marker	3
Other Structure	8

Category	Number of Resources
Park	1
Railroad	2
Road	21
Single Family Dwelling	2
Transmission	3
Water Conveyance/Management	5
Totals	**63**

Source: Eddy et al. 2024

Notes:

- Sixteen individual resources are within the Topock Compressor Station District, which is counted as one of three districts in this table.
- The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

For the 63 built environment resources identified in the study area, two are listed in the NRHP (the Old Trails Bridge near Topock and the Ocean-to-Ocean Highway Bridge in Yuma), six were recommended as eligible for the NRHP, 17 were recommended/determined ineligible (including the Topock Compressor Station District and Moapi Regional Park), while 38 have either not yet been evaluated (including the Picacho Squatters Settlement District), or NRHP status was not reported (Eddy et al. 2024). Parker Dam and its associated facilities were subject to a 1997 preliminary evaluation that concluded the dam complex is likely eligible as a district, therefore it is considered an NRHP-eligible historic district for the purposes of this Final Environmental Impact Statement (see Arizona above). The eight NRHP-listed/-eligible historic properties are summarized in **Table TA 11-16**.

Table TA 11-16
NRHP-Listed/-Eligible Historic Properties in the Study Area in California Listed from North to South

Resource Name/Type	Category	Property Type	NRHP Status	Criteria
National Trails Highway (Bat Cave Wash)	Transportation	Structure	Eligible	A
Historic U.S. Route 66	Transportation	Structure	Eligible	A
Old Trails Bridge (Topock Bridge)	Transportation	Structure	Listed	A, C
Parker Dam[a]	Water conveyance/ management	District	Eligible	A, C
All-American Canal	Water conveyance/ management	Structure	Eligible	A, C
Transmission Line (near Fort Yuma Riviera)	Electric Power	Structure	Eligible	D
Southern Pacific Railroad	Transportation	Structure	Eligible	D

Resource Name/Type	Category	Property Type	NRHP Status	Criteria
Ocean-to-Ocean Highway Bridge	Transportation	Structure	Listed	A, C

Source: Eddy et al. 2024
Note: The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.
[a] As previously mentioned, Parker Dam was subject to a preliminary assessment in California in 1997; a formal NRHP nomination is currently in progress for listing; therefore, the dam complex is included here as an NRHP-eligible district.

Nevada

In all, the Class I records search identified 22 built environment inventories that have been completed within the Nevada portion of the study area; these inventories were undertaken for several Lake Mead NRA improvements, transmission line construction, roadway improvements, resource evaluations, and NRHP eligibility determinations. Research identified 159 previously documented built environment resources, consisting mostly of properties (districts [i.e., groupings of resources], along with individual buildings, structures, sites, and objects) associated with the construction and ongoing operation of Hoover Dam on the Nevada side of the Colorado River (Winslow et al. 2024). As previously mentioned, the Hoover Dam Historic District was listed in the NRHP in 1981 and later designated an NHL in 1985. Because of the substantial number of district resources present on the Nevada side of the Colorado River, nearly all of which were given individual state-specific numbers, Hoover Dam is discussed in detail in this section as an NRHP-listed historic district.

In all, 98 individual built environment resources were documented as part of Hoover Dam, of which 66 are contributing (eligible), and 29 are noncontributing (ineligible) components of the NRHP-listed historic district, with the remaining 3 having no information pertaining to NRHP status. These include dam operational components (diverter towers, spillways, intakes, tunnels, penstocks, diversion channels, concrete support structures, and anchor foundations), cableway components (hoist house, crane towers, tower bases, and cable lines), electric power-related components (power plants, switchyards, transformers, and transmission lines), visitor services components (modern visitor facilities [not housed in operational buildings], parking lots and structures, food/beverage/gift shop facilities, historical monuments and interpretive installations, walking trail systems, and scenic overlooks), transportation components (access roads, gates, railroads and associated features, and bridges), and other components (unique and unclassifiable resources like spoils piles, survey markers, and memorials).

In addition to the Hoover Dam Historic District, there is one additional NRHP-listed historic property within the boundaries of Lake Mead NRA in the study area: Willow Beach Gauging Station (listed in the NRHP in 1986). Elsewhere in the Nevada study area, a total of 26 built environment resources associated with the development of recreation around Lake Mead and Lake Mohave within Lake Mead NRA have been given state-specific built environment resource numbers, consisting of 10 NRHP-eligible properties (including Echo Bay Developed Area, Cottonwood Cove Developed Area, and the Las Vegas Wash Developed Area) and 16 ineligible properties (including Boulder Beach Developed Area District, Callville Bay Developed Area, and Overton Beach

Developed Area District). At the south end of Lake Mohave is Davis Dam, and because most of the dam complex is on the Arizona side of the river, only three components of the dam have been documented and given inventory numbers, and all are eligible for the NRHP (Winslow et al. 2024).

Furthermore, 23 built environment resources identified in the Nevada study area were documented on an individual basis (apart from Hoover and Davis Dams and established recreation areas in Lake Mead NRA), including 11 NRHP-eligible properties and five NRHP-ineligible properties, leaving eight properties where NRHP status information was absent in the archival record (Winslow et al. 2024). Half of these resources represent individual overhead powerlines that are owned and maintained by various utility entities (federal, state, municipal, private), bringing electricity generated at both Hoover and Davis Dams to their respective service areas primarily in Southern California. The other half consists of transportation (road segments), non-electric power utility (the Boulder City water supply line, a telephone line), science and research (U.S. Geological Survey [USGS] monitoring facilities), resources that have been given state-specific built environment numbers. Lastly, there are six built environment resources for which no information (e.g., resource category, property type, NRHP status, and jurisdiction/ownership) was available from corresponding archives. **Table TA 11-17** summarizes the built environment resources by category (i.e., function and/or use) along with corresponding property types and NRHP status as identified in the Nevada portion of the study area.

Table TA 11-17
Built Environment Resources Documented in the Study Area in Nevada

HOOVER DAM

Category	Property Type	NRHP Status (Criteria)	Resource Count	Jurisdiction/ Ownership	Administering Agency
Dam Operations	Building	Eligible (A and/or C)	4	Reclamation	LCRO
		Ineligible	3	Reclamation	LCRO
	Structure	Eligible (A and/or C)	19	Reclamation	LCRO
		Ineligible	1	Reclamation	LCRO
		Total	**27**	—	—
Cableway	Building	Eligible (A and/or C)	1	Reclamation	LCRO
	Structure	Eligible (A and/or C)	4	Reclamation	LCRO
		Total	**5**	—	—
Electric Power	Building	Eligible (A and/or C)	2	Reclamation	LCRO
	Structure	Eligible (A and/or C)	15	DOE, Reclamation, Municipal	WAPA, LCRO, LADWP
		Ineligible	19	Unknown	Unknown
		Total	**36**	—	—

HOOVER DAM

Category	Property Type	NRHP Status (Criteria)	Resource Count	Jurisdiction/ Ownership	Administering Agency
Visitor Services	Building	Eligible (A and/or C)	1	Reclamation	LCRO
		Ineligible	2	Reclamation	LCRO
	Structure	Eligible (A and/or C)	4	Reclamation	LCRO
		Ineligible	2	Reclamation	LCRO
	Object	Eligible (A and/or C)	1	Reclamation	LCRO
		Ineligible	1	Reclamation	LCRO
		Unknown	1	Reclamation	LCRO
		Total	**12**	—	—
Transportation	Structure	Eligible (A and/or C)	12	Reclamation	LCRO
		Ineligible	1	Reclamation	LCRO
		Total	**13**	—	—
Other	Structure	Ineligible	1	Reclamation	LCRO
	Site	Eligible (A and/or C)	2	Reclamation	LCRO
		Unknown	1	Reclamation	LCRO
	Object	Eligible (A and/or C)	1	Reclamation	LCRO
		Total	**5**	—	—
		HOOVER DAM RESOURCE TOTAL	**98**		

LAKE MEAD / LAKE MOHAVE

Category	Property Type	NRHP Status (Criteria)	Resource Count	Jurisdiction/ Ownership	Administering Agency
Recreation	District	Eligible	3	NPS	Lake Mead NRA
		Ineligible	3	NPS	Lake Mead NRA
	Building	Eligible (A and/or C)	5	NPS	Lake Mead NRA
		Ineligible	11	NPS	Lake Mead NRA
	Structure	Eligible (A and/or C)	2	NPS	Lake Mead NRA
	Site	Ineligible	2	NPS	Lake Mead NRA
		LAKE MEAD / LAKE MOHAVE RESOURCE TOTAL	**26**		

DAVIS DAM

Category	Property Type	NRHP Status (Criteria)	Resource Count	Jurisdiction/ Ownership	Administering Agency
Transportation	Structure	Eligible (A and/or C)	1	Reclamation	LCRO
		Total	**1**		
Other	Site	Eligible (A and/or C)	2	Reclamation	LCRO
		Total	**2**		
		DAVIS DAM RESOURCE TOTAL	**3**		

INDIVIDUAL

Category	Property Type	NRHP Status (Criteria)	Resource Count	Jurisdiction/ Ownership	Administering Agency
Electric Power	Structure	Eligible (A and/or C)	7	DOE, State, Municipal, Private	WAPA, MWD, LADWP, SCE
		Ineligible	3	DOE, Private	WAPA, NV Energy, SWGC
		Unknown	2	Private	SCE
		Total	**12**		
Recreation	Building	Unknown	5	NPS	Lake Mead NRA
		Total	**5**		
Transportation	Structure	Eligible (A and/or C)	1	NPS	Lake Mead NRA
		Ineligible	1	Reclamation	LCRO
		Total	**2**		
Utility (Non-Electric)	Structure	Eligible (A and/or C)	1	Reclamation	LCRO
		Unknown	1	Unknown	Unknown
		Total	**2**		
Science/Research	Building	Eligible (A and/or C)	1	Unknown	Unknown
	Structure	Eligible (A and/or C)	1	Unknown	Unknown
		Total	**2**		
		INDIVIDUAL RESOURCE TOTAL	**23**		

UNKNOWN					
Category	**Property Type**	**NRHP Status (Criteria)**	**Resource Count**	**Jurisdiction/ Ownership**	**Administering Agency**
Unknown	Unknown	N/A	6	Unknown	Unknown
		UNKNOWN RESOURCE TOTAL	**6**		

Source: Winslow et al. 2024
Notes:

- Jurisdiction is given only for the study area and is based on ownership information in NVCRIS; WAPA (Western Area Power Administration) is under the DOE (Department of Energy); the Southern Nevada Fish and Wildlife Office is part of the FWS. Other administering entities include MWD (Metropolitan Water District of Southern California), LADWP (Los Angeles Department of Water and Power), SWGC (Southwest Gas Corporation), SCE (Southern California Edison), and Nevada Department of Wildlife. For transmission lines, shared jurisdictional responsibility is not uncommon; however, this is not reflected in this table. For components of the Hoover Dam Historic District, resources noted as eligible are contributing components of the district, while ineligible resources are noncontributing components. For Lake Mead and Lake Mohave—two districts (Boulder Beach [ineligible] and Las Vegas Wash Campground [eligible]), each encompasses a share of the buildings, structures, and sites listed separately.
- The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Utah

The Class I records search identified one built environment resource within the Utah portion of the study area—Hite Crossing Bridge—which was previously documented and recommended as eligible for the NRHP under Criterion C (Eskenazi 2024). Also known as the Colorado River Arch Bridge, it spans the river connecting Utah State Route 95 near Hite Marina within the boundaries of Glen Canyon NRA. Part of the Trail of the Ancients National Scenic Byway and the Utah Bicentennial Highway Scenic Byway, the Hite Crossing Bridge is under the management of the Utah Division of Transportation.

Specially Designated Cultural Resources

As previously mentioned, there are three different types of special designations identified in the study area—that of the NHL, as well as the congressionally designated NHA and the NHT. NHLs are historic properties that illustrate U.S. heritage, while NHAs are nationally important landscapes encompassing unique natural, cultural, and scenic values. NHAs are not managed by the federal government, rather, they are managed by state governments, non-profit organizations, or private entities. Lastly, NHTs follow past routes of exploration, migration, trade, struggle, and/or military action representing historic corridors of national significance, which may or may not have a present physical manifestation. With some exceptions, administration of an NHT is generally assigned to a single federal agency (NPS, BLM, or U.S. Forest Service), with on-site jurisdiction belonging to various governmental agencies or private entities that own or manage the lands along each NHT.

The specially designated areas intersecting the study area are briefly summarized below by state, with more detailed discussions presented in the respective state volumes prepared to support this Final Environmental Impact Statement (Eddy et al. 2024; Eskenazi 2024; Tremblay et al. 2024b; Winslow et al. 2024). It should be noted that there are five specially designated areas crossing the study area in

more than one state including two NHLs and three NHTs—Hoover Dam NHL (Arizona and Nevada within Lake Mead NRA), Yuma Crossing NHL (Arizona and California), the Armijo Route (Arizona and Utah within Glen Canyon NRA) and the Mojave Road route (Nevada within Lake Mead NRA) of the Old Spanish NHT, as well as the Juan Bautista de Anza NHT and the recently designated Butterfield Overland NHT (Arizona and California).

Arizona

The Class I records search identified nine NHLs that intersect the Arizona portion of the study area—five districts and four individual buildings (Tremblay et al. 2024b). Most of the NHLs in the study area are within GCNP, including two districts and four buildings on the South Rim and one on the North Rim, all of which are administered by the NPS. The remaining two NHLs outside of GCNP are Hoover Dam and Yuma Crossing. Hoover Dam is under the jurisdiction of Reclamation and is situated within the boundaries of Lake Mead NRA but is not part of the NPS-administered park. The NHL designation encompasses infrastructure in both Arizona and Nevada, with the majority of components on the latter side of the river. Yuma Crossing NHL is unique in that it is composed of five distinct individual areas (including two state parks) that are collectively also designated as an NHA. The NHL designation encompasses portions of the study area in both Arizona and California while the NHA boundary only includes Arizona. The NHA is managed by a non-profit organization.

For the Arizona study area, the Armijo Route of the Old Spanish NHT crosses portions of Lake Powell within Glen Canyon NRA, while both the Juan Bautista de Anza NHT and the recently designated Butterfield Overland NHT traverse the river corridor in the Yuma area. There are no known physical remnants of the Old Spanish NHT in Arizona and if present, such evidence would be under the waters of Lake Powell. The routes of the Juan Bautista de Anza NHT and the Butterfield Overland NHT are approximate through the study area and, likewise, there is no known physical evidence of any original trail sections for either NHT. Therefore, there are no known NRHP-eligible segments of any of the three NHTs (Tremblay et al. 2024b).
Table TA 11-18 summarizes the specially designated areas (NHLs, NHAs, and NHTs) in the Arizona study area.

Table TA 11-18
National Historic Landmarks, National Heritage Areas, and National Historic Trails in the Study Area in Arizona

NATIONAL HISTORIC LANDMARKS

Name	Year Designated	Property Type	Jurisdiction/Ownership	Administering Agency
*M.E.J. Colter Buildings	1987	District	GCNP	NPS
*El Tovar Hotel	1987	Building	GCNP	NPS
Grand Canyon Lodge (North Rim)	1987	District	GCNP	NPS
*Grand Canyon Depot	1987	Building	GCNP	NPS
*Grand Canyon Park Operations Building	1987	Building	GCNP	NPS

NATIONAL HISTORIC LANDMARKS

Name	Year Designated	Property Type	Jurisdiction/Ownership	Administering Agency
*Grand Canyon Power House	1987	Building	GCNP	NPS
Grand Canyon Village	1997	District	GCNP	NPS
Hoover Dam	1985	District	Federal	Reclamation
Yuma Crossing and Associated Sites	1966	District	Multiple (tribal, state, city)	N/A

NATIONAL HERITAGE AREAS

Name	Year Designated	Property Type	Jurisdiction/Ownership	Administering Agency
Yuma Crossing	2000	N/A	Multiple (state, city)	Non-profit

NATIONAL HISTORIC TRAILS

Name	Year Designated	Property Type	Jurisdiction/Ownership	Administering Agency
Old Spanish Trail (Armijo Route)	2002	N/A	Glen Canyon NRA	NPS
Juan Bautista de Anza Trail	1990	N/A	Multiple (tribal, state, city, private)	NPS
Butterfield Overland Trail	2023	N/A	Multiple (tribal, state, city, private)	NPS

Source: Tremblay et al. 2024b

Notes:

- Jurisdiction and ownership are given only for the study area.
- NHLs, when designated, are automatically listed in the NRHP if not already. NHLs in this table that also contribute to other NRHP-listed historic districts are indicated with an asterisk (*) and may also be repeated in subsequent applicable table(s). The M.E.J. Colter Buildings NHL consists of four isolated buildings on the South Rim (Lookout Studio, Hopi House, Desert View Watchtower, and Hermit's Rest), of which two (Lookout Studio and Hopi House) contribute to the significance of the Grand Canyon Village NHL. NHLs in GCNP are spatially separated from the river corridor because of substantial vertical distance and intervening terrain in Grand Canyon. Yuma Crossing NHA encompasses Yuma Territorial Prison State Park, Colorado River State Park, Yuma East Wetlands, Yuma West Wetlands, and Pivot Point Plaza. The Grand Canyon (North Rim) Lodge was designated as an NHL in 1987 along with its associated cabins; however, the main lodge was recently lost during the 2025 Dragon Bravo Fire, along with several cabins. While it is still designated as an NHL, it has been mostly destroyed by wildfire and its status is likely to change; therefore, this NHL has been removed from consideration.
- The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

California

The Class I records search identified one NHL—Yuma Crossing—which extends across the Colorado River into California to encompass the site of Fort Yuma, a former nineteenth century U.S. military post now on the Fort Yuma-Quechan Reservation (Eddy et al. 2024). There are no NHAs in the California portion of the study area because the Yuma Crossing NHA designation only

includes the portion of the NHL on the Arizona side of the river. For the portions of the Juan Bautista de Anza NHT and Butterfield Overland NHT that cross the study area in California, there is no physical evidence of original trail segments known to exist.

Nevada

The Class I records search identified two specially designated cultural resources intersecting the study area—Hoover Dam NHL and the Mojave Road route of the Old Spanish NHT (Winslow et al. 2024). Hoover Dam NHL was designated in 1985, spanning two states, encompassing half the dam along with extensive electrical infrastructure on the Nevada side of the river, including primary visitor services. The Old Spanish NHT corridor enters the Nevada study area along the Virgin River and is submerged under the Overton Arm of Lake Mead. It exits the study area near Boulder Wash Cove and reenters at Callville Bay before exiting again at Las Vegas Bay. There are no known original segments of the Old Spanish NHT within the Nevada portion of the study area, and if remnants do exist, they were submerged when Lake Mead was impounded and would be underwater.

Utah

Based on the Class I records search, there is only one congressionally designated area in the Utah portion of the study area—the Armijo Route of the Old Spanish NHT—which crosses into the study area within Glen Canyon NRA (Eskenazi 2024). There are no known segments of the original trail documented within the Utah portion of the study area. Like Lake Mead, if such do exist, they are inundated under the waters of Lake Powell.

Cultural Landscapes

There are different definitions for what constitutes a cultural landscape, however, at its basic level, a cultural landscape is a geographic area, encompassing both cultural and natural resources, that illustrates evidence of human interaction with the physical environment. The only defined cultural landscapes in the study area are within GCNP, where NPS has identified 16 cultural landscape areas in the park, representing historically or culturally significant designed, vernacular, and ethnographic landscapes, which allows land managers to assess how these landscapes should be managed and interpreted (NPS 2024). Most of the cultural landscapes identified in GCNP are spatially separated from the river corridor because of vertical distance and/or intervening canyon terrain. The Colorado River and its associated uplands represent a cultural landscape with both tangible and intangible attributes for many Indigenous peoples. Natural resources, such as animals, plants, springs, rivers, land formations, and human-made elements, such as ancestral homes and trails, fields, prayer objects enshrined in travertine and salt, are all important aspects of a cultural landscape. Tribal perspectives on cultural landscapes are summarized in **TA 13**, Tribal Resources.

The historic landscape at Lees Ferry, a recreation site at the confluence of the Colorado and Paria rivers in Glen Canyon NRA, is an example of a managed cultural landscape encompassing the NRHP-listed Lee's Ferry and Lonely Dell Ranch Historic District, which represents over 60 years of non-Indigenous cultural use of the Colorado River beginning with the establishment of the first ferry crossing by John D. Lee in 1871 up to 1909 when the Church of Jesus Christ of Latter-day Saints divested itself from both the ferry and farmstead. Lee's Ferry was the only ferry crossing of the Colorado River within 700 miles because, here, the river was not bound by steep canyon walls,

allowing wagons to be driven to the river's edge. Historically, Lee's Ferry operated as a ferry crossing and farmstead with an extensive irrigation system, which today are represented by several historic-era buildings, a cemetery, an orchard, trails, and fields. The Lee's Ferry and Lonely Dell landscape is an interpretative site that is still used today by day visitors, river runners, campers, and the USGS for their river gauging stations.

Traditional Cultural Places

A TCP, which is a type of historic property, is "a building, structure, object, site, or district that may be eligible for inclusion in the National Register for its significance to a living community because of its association with cultural beliefs, customs, or practices that are rooted in the community's history and that are important in maintaining the community's cultural identity" (NPS 2024). Because the TCPs of concern are those of Indigenous peoples, the analysis of impacts on TCPs is found in **TA 13**, Tribal Resources.

TA 11.2 Environmental Consequences

TA 11.2.1 Methodology

Direct and indirect impacts on cultural resources could result from changes in lake levels or river flows from the annual releases. Of greatest concern are effects on historic properties (i.e., resources eligible for or listed in the NRHP) that alter the characteristics of the properties in a way that would diminish the integrity of its location, design, setting, materials, workmanship, feeling, or association (36 CFR 800.5). Direct impacts may be from processes such as wave action and wet-dry cycling, but include any impact that is immediate in place and time, including visual, auditory, and atmospheric impacts; indirect impacts, such as from increased ease of access to previously inundated sites, are those that occur farther away in distance and/or later in time.

Impacts on cultural resources analyzed in this section only include those impacts resulting from Reclamation's management of annual releases from Glen Canyon and Hoover dams. The analysis emphasizes cultural resources within 20 meters (66 feet) of the river corridor because they are the most likely to be affected by changes in river flows.

Archaeological Sites

Three types of analyses are used to discuss potential impacts on archaeological resources: known site counts by elevation and modeled lake elevations/known sites counts within 20 meters (66 feet) of the river corridor, preservation risk modeling developed by the USGS and NPS, and aeolian transport modeling also developed by the USGS. Elevations for sites identified in the Class I records search at Lake Powell and Lake Mead were calculated and used to identify those sites that are at elevations subject to changes in water levels. However, due to the low Class III survey coverage, there are doubtless more sites to be found. Archaeological data over broad areas are, by virtue of how and when the data were collected, variable in coverage and documentation. For example, areas around Lake Powell have a higher cultural resource survey coverage and therefore, more archaeological data are available, while areas around Lake Mead do not. Also, there is very limited data on archaeological sites below the water line due to a lack of studies prior to inundation in Lake Mead NRA.

Along the river corridor, the analysis focuses on sites identified within 20 meters (66 feet) of the river corridor (bank to bank). A 20-meter (66-foot) distance is used because the variability of elevation along the river corridor is too great to efficiently sort thousands of sites by elevation; this distance corresponds to the most likely impacted zone from the Class I report (Tremblay et al. 2024b; Winslow et al. 2024).

Inundated Resources and Water Levels

Fluctuating water levels at Lake Powell and Lake Mead can impact the preservation of archaeological sites, especially for those that are currently or previously inundated. The NPS prepared an initial study of how inundation and fluctuating water levels at Lake Powell affect resources (Morgan and Conlin 2023), which generally parallel the findings of earlier archaeological inundation studies (e.g., Lenihan et al. 1981a, 1981b; Ware 1989). Archaeological resources are more vulnerable to disturbance and degradation when water levels fluctuate. Fluctuating water levels can result in increased wave impacts, wet-dry cycling, freeze-thaw cycling, and erosion.

Differences in topography and elevation in the lake reservoirs, as well as the length of exposure, affect the impact on sites. The reservoirs, in the cross section, are wide at the higher elevations and narrow at the lower elevations, where the lake fills what were steep-sided and deep canyons. In areas where the topography is flatter, at higher elevations, changes in lake elevation take longer, and the reservoir volume fluctuation exposes more horizontal area, while in the steeper areas, like canyons, changes in lake elevation may be faster and reservoir volume fluctuation occurs in a much more volatile fashion. In the lower reaches of the narrow canyons, removal or addition of a small amount of water will raise or lower the lake significantly; this may occur multiple times due to normal reservoir operations and will be relatively rapid. Higher in the canyons, removal or addition of water will raise or lower the lake by a smaller amount, leading to more extended periods of impacts due to wave actions and freezing and thawing.

Changes in temperature, water chemistry, pH, salinity, and sedimentation as water levels rise and fall can also be detrimental to the preservation of resources. While inundation is also not ideal, as it can displace artifacts and disturb and damage site components sensitive to water or moisture (like mud mortar), inundation can protect resources through sedimentation, if it is consistent over time. Inundation can also prevent weathering and provide a low oxygen environment that can protect artifacts. Resources that have previously been inundated and are exposed through fluctuating water levels are particularly vulnerable to wave action, etc., as well as to impacts from visitation. Like fluctuating lake levels, changes in river flows may impact archaeological sites through erosion, wet-dry cycling, exposure to the elements, and increased visitation of exposed resources. Discussion of lake elevations is based on minimum water-year (WY) and end-of-water-year (EOWY) elevations for Lake Powell, and minimum calendar-year (CY) and end-of-calendar-year (EOCY) elevations for Lake Mead (see **TA 3**, Hydrologic Resources). The analysis references applicable tables presented in **TA 3** for corresponding elevations (in feet) at Lake Powell (minimum WY and EOWY) and Lake Mead (minimum CY and EOCY) for each of the different hydrological conditions under different modeled scenarios. These include the maximum, 90th percentile, 75th percentile, median (50th percentile), 25th percentile, 10th percentile, and minimum elevations. The analysis also references applicable figures in **TA 3** that visualize the elevation data for Lake Powell and Lake Mead using side-by-side conditional box plots where the bold lines through each box represents the median

elevation (50th percentile), the top and bottom of each box captures the 25th and 75th percentile of the modeled results (the interquartile range), the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines (maximum and minimum elevation ranges for the modeled results). Specific tables and figures from **TA 3**, Hydrologic Resources, are called out as appropriate in each section below.

Preservation Risk Modeling

The USGS, in cooperation with NPS, developed a model to assess "preservation risk" for archaeological resources at or below full pool elevation at Lake Powell and Lake Mead (Caster et al. 2026). This Preservation Risk model is a spatial model that considers several landscape characteristics, locations of previously recorded cultural resources, and potential for water-related impacts, such as wave action and erosion. The lake landscape was gridded off into 10-meter resolution cells, and each 10-meter resolution grid cell within the model was categorically ranked 1 to 5 based on low (1) to high (5) potential for site preservation to be negatively affected by water at a given reservoir elevation. The Preservation Risk model incorporates two other models: the Site Distribution model, which identifies where archaeological resources are more likely or less likely to be found, and the Preservation Hazard model, which identifies where site impacts related to lake fluctuations will likely occur.

Specific for archaeological sites, the Site Distribution model is based on landscape characteristics (geologic and geomorphic context-geologic maps and digital elevation models [DEMs]), topographic position-DEMs/bathymetry, proximity to major runoff flow concentrations seen in National Hydrology Dataset flowlines and DEMs, and known locations of archaeological sites (precontact and postcontact). As mentioned above, not all of Lake Powell was surveyed prior to the completion of Glen Canyon Dam construction, and very little of Lake Mead prior to when filling began in 1934, so this model allows for the prediction of site distribution based on the correlation of landscape characteristics to known site location. However, the known site distribution was used within Lake Powell (a larger percent surveyed) to help define the distribution ranks (Rank 1 – no known archaeological sites, Rank 2 – known site density less than 1.5 per square mile (2.6 square kilometer), Rank 3 – known site density greater than and equal to 1.5 per square mile and less than 3 per square mile, Rank 4 – known site density greater than and equal to 3 per square mile and less than 4.5 per square mile, and Rank 5 – known site density greater than and equal to 4.5 per square mile).

The Preservation Hazard model is based on the simplified physical factors influencing lake shore geomorphic change. Like with coastal environments, wave action is a major player in erosion, but reservoirs have the added risk of large, rapid, and sustained changes in water level that affect runoff base level conditions, soil deformation, and chemical weathering with submersion and exposure. These aspects were incorporated into the model using available USGS topography and bathymetric data and the known relationships between slope-wave interactions/baselevel adjustments, lake fetch lengths (distance wind travels over water surfaces to help build waves), and lake shoreline area change, as well as a given change in elevation. In this model, the highest rank (5) correlates to a higher potential for impacts, and the lowest rank (1) correlates to a lower risk from these factors.

When combining the Site Distribution and Preservation Hazard models, a simple rule set was used based on the assumptions that: 1) regardless of hazard rank, areas likely to contain resources have

potential to be affected by dam management operations; 2) even where archaeological resource likelihood is low, hazards from water levels can impact a potentially significant site; 3) areas with very high likelihood of containing archaeological sites and very high potential for impacts are at the highest risk of resource condition changes; and 4) areas with very low likelihood of containing archaeological sites and very low potential for impacts are at the lowest risk of resource condition changes.

The above concepts allow for each grid cell in the reservoir footprint to be ranked. For the analysis, the Preservation Risk model was summarized for greater than 60 units of 10-foot elevation bins at and below full pool. The summaries represent statistics of the Preservation Risk rank at the lake shoreline between the upper and lower reservoir elevations, defining each 10-foot bin (i.e., each bin represents a different summary area). Monthly modeled reservoir values are used in this model. In this way, each monthly modeled reservoir level will fall into one of the 10-foot summary bins and can be assigned a preservation risk rank summary statistic, such as the mean risk rank, that represents generalized potential impacts along the lake shoreline for that reservoir level. Monthly risk values, based on reservoir elevations, can then be used to evaluate differences between scenarios and traces within the modeling period.

Wind-deposited Sediment

Research conducted by the USGS and NPS has demonstrated that wind-deposited (aeolian) sediment can help stabilize and preserve archaeological sites along the Colorado River over long periods of time (East et al. 2016; Sankey et al. 2023). Fine sand or sediment can be blown from flow-deposited source areas and deposited on cultural sites (East et al. 2016). The effects of deposition or erosion may be negative or positive depending on the nature of the site. One important recent finding is that sandbars created by high-flow events at Glen Canyon Dam can provide sources of windblown sand that can cover archaeological sites (East et al. 2016) as well as anneal, or reverse, the formation of gullies (Sankey and Draut 2014). In this context, changes in dam operations can affect erosion rates on archaeological sites (East et al. 2016; Collins et al. 2016). Sediment is generally deposited via wind on nearby terraces with archaeological sites at an average rate of a few millimeters a year; however, operations of the Glen Canyon Dam can inhibit the formation of sand bars from which the sediment is blown. Management of the Colorado River influences the supply of windblown river sand in two ways: (1) the reduction of river flows below current average baseflow levels causes sand in the river channel to be exposed subaerially and, given sufficient time, can dry out and become available for wind transport (Sankey et al. 2022); and (2) when high-flow experiments (HFEs) are successfully implemented to rebuild river sandbars, the sand in the subaerial portion of the sandbars becomes available for wind transport in the Grand Canyon (Caster et al. 2022; Sankey et al. 2018). However, riparian vegetation can block the windblown transport of sand; when vegetation cover decreases, the potential for wind transport increases (Sankey et al. 2023).

The analysis integrated three independent models: the aeolian sand availability model (hereafter referred to as the "Sand Area model"; Kasprak et al. 2024; Kelley et al. 2026), the Vegetation Habitat Suitability model (Butterfield et al. 2018; Butterfield and Palmquist 2026), and the Sandbar Volume model (initially modified from Mueller and Grams 2021; Salter and Grams 2026). The Sand Area model was specifically developed to predict the supply of river-sourced, windblown sand as a function of river discharge and subaerial exposure time; however, the Sand Area model used here

does not incorporate changes in vegetation cover that occur as a function of river hydrology or geomorphic changes (deposition and erosion of sand) that would also affect sand area. Therefore, the Sand Area model was then coupled with the outputs with those from the Marble Canyon Vegetation Habitat Suitability model. Scenarios were assessed in which modeled sand availability exceeded a defined threshold while vegetation suitability remained below a specified benchmark—conditions presumed to favor increased aeolian transport.

To further capture the dynamic influence of high-flow events, which can increase sandbar volume and enhance future sand supply, the Sandbar Volume model output was then included in the evaluation framework. In this analysis, a future is defined as a "preferred minimum performance" if one of the following logical criteria was met: (1) the Sand Area model exceeded and the Vegetation Habitat Suitability model simultaneously fell below their respective thresholds (suggesting favorable conditions for aeolian transport), or (2) the Sandbar Volume model exceeded the threshold, indicating enhanced sand supply via fluvial-related deposition. Previous work suggests that dam releases that allow for these conditions to be met at least once every 1–3 years may slow the rate of degradation to enable time for proactive mitigation and planning (Sankey et al. 2018). Considering temporal variability of future preferred minimum performance, it is a preferred minimum performance if these conditions are met at least once every 3 years.

Model thresholds were derived from recent historical baselines: the sand area and vegetation (Marble Canyon only) thresholds reflect the 50th percentile of model outputs from 2000 to 2023, while the sandbar volume threshold is set at 1.5 times the modeled initial condition beginning in 2027. For sandbars to grow in volume and provide a continuous supply of river sand for aeolian transport to protect cultural resources, HFEs must be conducted on a frequent basis (e.g., every 1–3 years). However, the frequency of HFE occurrence, and thus sandbar volume growth, is likely overpredicted in the modeling, as the decision for an HFE to occur or not in a given year is a policy decision based on environmental conditions and other factors.

Built Environment Resources

No modeling was conducted specifically for built environment resources. Recalling that built environment resources are those human-made and/or intentionally modified components of our environment, these types of resources are much less vulnerable to impacts compared to archaeological resources. The most prominent of the built environment resources identified in the study area also constitute critical infrastructure, constructed as part of major Reclamation projects like Glen Canyon Dam, Hoover Dam, as well as Davis and Parker dams. This also includes the smaller dams like the Palo Verde Diversion Dam, Imperial Dam, Laguna Dam, and Morelos Dam, along with the various canals and levee systems in the lowest reaches. Collectively, these facilities are key to Colorado River operations, and none of the alternatives would result in the decommissioning or substantial alteration of such critical infrastructure, so the historic importance of these resources would not be jeopardized. Therefore, it is assumed there would be no direct or indirect impacts on this critical infrastructure, and they are not carried forward for analysis.

In terms of built environment resources around the reservoirs and immediately along the river corridor that are not considered critical infrastructure for river operations, these properties were developed in response to either the creation of both Lake Powell and Lake Mead or to provide

access to and/or across the river itself. Historic-era transportation roadway and railway networks spanned the river via bridges, while trails were established to provide river access. Recreation areas like those identified in Lake Mead NRA were intentionally placed in locations that took advantage of proximity to water. Other tourist facilities, like those in GCNP, were designed to accommodate visitors near the river and provide safe crossing between the North and South Rims. As such, for most built environment resources in the study area, these types of properties were designed or located in consideration of fluctuating water levels both around the reservoirs and the river corridor. They are not considered vulnerable to inundation or varying water levels, increased wave impacts, wet-dry cycling, or erosion like archaeological sites because they were designed to withstand or avoid those impacts historically. Therefore, impacts on NRHP-listed and NRHP-eligible built environment resources would occur where uncharacteristic water levels and river flows exceed historical ranges.

Specially Designated Cultural Resources

No modeling was undertaken for NHLs, NHAs, or NHTs. The one NHA identified in the study area (Yuma Crossing) coincides with the Arizona portion of the Yuma Crossing and Associated Sites NHL; therefore, it is analyzed as an NHL. There are no confirmed segments of the original trail in the study area for the three NHTs. Impacts on NHLs, as the only specially designated cultural resources identified in the study area, could occur only if river flows are outside the historical ranges.

Impact Analysis Area

The impacts analysis area consists of the Colorado River corridor from the upper limits of Lake Powell in Utah, through the Grand Canyon in Arizona, and Lake Mead in Arizona, and from Hoover Dam to the SIB.

Assumptions

- Once a resource has been inundated by a reservoir, being continuously inundated thereafter is more conducive to preservation than repeated cycles of inundation and exposure (i.e., wet-dry cycling and wave action).
- Repeating cycles of inundation and exposure of resources by the reservoirs and/or the river are damaging to archaeological resources.
- The covering of resources by wind-deposited, river-sourced sediment is conducive to preservation.
- While HFEs were considered in the aeolian transport model as part of the individual vegetation and sandbar models, actual HFE frequency may differ from that assumed or predicted in the modeling.
- Impacts on cultural resources can be characterized based on projected minimum and end-of-year lake elevations for very wet through very dry conditions and river flow volumes.
- Cultural resources that have not been previously inundated would not be inundated under the Continued Current Strategies (CCS) Comparative Baseline, the No Action Alternative, or any action alternatives (i.e., no cultural resources located above reservoir spillway elevations or above the level of current river flows would be inundated).

- The limit of physical impacts on cultural resources by the river is constrained to resources within the river corridor (bank to bank) or within 20 meters (66 feet) of the river.
- Where previous survey coverage is absent within the study area, there may be sites that have not yet been identified (i.e., undiscovered) that could be affected under the CCS Comparative Baseline, the No Action Alternative, or any action alternatives.
- The Class I records search conducted for the study area in Arizona, California, Nevada, and Utah serves as a representative dataset for the purposes of analysis.
- Lake Mohave and Lake Havasu would continue to follow their target end-of-the-month elevation schedules ("rule curve") (see **TA 3**, Hydrologic Resources), therefore, no cultural resource impacts are expected at these reservoirs.

Impact Indicators

- Projected monthly and end-of-year lake elevations that may expose cultural resources to damage from wave action, wet-dry cycling, or increased ease of access
- Projected WY and CY dam releases resulting in potential river-flow changes that leave cultural resources susceptible to damage from erosion, wet-dry cycling, or increased ease of access
- Projected availability of sediments along the river, which may be transported by wind and deposited on archaeological sites

TA 11.2.2 Issue 1: How will any changes in dam operations affect (1) lake elevations at Lake Powell and Lake Mead and (2) river flows downstream, which may affect cultural resources?

Lakes

As water levels in Lake Powell and Lake Mead fluctuate, archaeological sites that were previously inundated become vulnerable to several hazards. Direct impacts from wave action, wet-dry cycling, and erosion are more likely to occur as water levels drop to expose previously inundated resources; indirect impacts may occur from increased visitor traffic as access to exposed resources becomes easier. This section discusses the potential for archaeological resources to be exposed, and therefore potential impacts from exposure, using the distribution by elevation of cultural resources and the hydrologic modeling results for Lake Powell and Lake Mead elevations. However, please note that more data was available for Lake Powell than for Lake Mead because of variable archaeological survey coverage. The following discussion incorporates the discussion of hydrological modeling as presented in **TA 3**, Hydrologic Resources.

Because survey coverage varies across the study area and much of the locational data for recorded sites predates modern technology, precise site counts are not feasible for analysis. Instead, site counts should be considered a representative sample used to understand the overall level of sensitivity within the study area. Representative site counts by elevation were compiled from Class I data using associated elevations based on critical conditions for each lake, which are discussed in **TA 3**, Hydrologic Resources. For Lake Powell, the associated elevations for critical conditions pertinent to this analysis are 3,700 feet (top of the Glen Canyon Dam spillway) down to 3,490 feet (minimum power pool; see **Table TA 3-2** in **Section TA 3.2.1** of **TA 3**, Hydrologic Resources). For

Lake Mead, these associated elevations for critical conditions pertinent to this analysis are 1,221 feet (top of the Hoover Dam Spillway) down to 950 feet (minimum power pool; see **Table TA 3-5** in **Section TA 3.2.1** of **TA 3**, Hydrologic Resources).

Archaeological sites identified in the Lake Powell dataset are presented by elevation range in **Table TA 11-19**, while those identified in the Lake Mead dataset are presented (also by elevation range) in **Table TA 11-20**. Overall survey coverage for both lakes is very low (around 3 percent), which means the numbers in **Table TA 11-19** and **Table TA 11-20** greatly underrepresent the total number of sites present.

Table TA 11-19
Recorded Archaeological Sites in the Lake Powell Dataset by Elevation Range (Arizona and Utah)

Elevation Range (feet)	Elevation Range (meters)	No. of Sites (NPS)	No. of Sites (non-NPS)	Total
3,700–3,680	1,128–1,122	66	N/A	66
3,680–3,660	1,122–1,116	40	N/A	40
3,660–3,640	1,116–1,109	32	N/A	32
3,640–3,620	1,109–1,103	59	N/A	59
3,620–3,600	1,103–1,097	52	N/A	52
3,600–3,580	1,097–1,091	31	N/A	31
3,580–3,560	1,091–1,085	36	N/A	36
3,560–3,540	1,085–1,079	34	N/A	34
3,540–3,520	1,079–1,073	31	N/A	31
3,520–3,500	1,073–1,067	34	N/A	34
<3,500	<1,067	442	N/A	442
			Total Sites in the Lake Powell Dataset	**857**

Source: Glen Canyon NRA staff
Notes:

- N/A = not applicable; all lands within Glen Canyon NRA are NPS lands.
- Glen Canyon NRA staff provided updated NPS site counts by elevation in March 2026, stating that lands within the study area under 3,580 feet are NPS lands and should be accounted for in the updated data; therefore, the non-NPS data acquired during the Class I records search (which relies on agency data acquired in August 2023) have been omitted. Therefore, this table does not correlate with the NPS site counts (or the total number of sites) identified by the Class I records search.
- Survey coverage at Lake Powell is calculated to be 3.3 percent of the area below full pool meaning the number of sites in the Lake Powell data set represents a fraction of the total number of sites present.

Table TA 11-20
Recorded Archaeological Sites in the Lake Mead Dataset by Elevation Range (Arizona and Nevada)

Elevation Range (feet)	Elevation Range (meters)	No. of Sites (NPS)	No. of Sites (non-NPS)	Total
1,221–1,201	372–366	75	10	85
1,201–1,181	366–360	49	8	57
1,181–1,161	360–354	52	2	54
1,161–1,141	354–348	27	4	31
1,141–1,121	348–342	13	5	18
1,121–1,101	342–336	17	3	20
1,101–1,081	336–329	8	2	10
1,081–1,061	329–323	5	ND	5
1,061–1,041	323–317	6	ND	6
1,041–1,021	317–311	5	ND	5
1,021–1,001	311–305	5	ND	5
1,001–981	305–299	5	ND	5
981–961	299–293	5	ND	5
<961	<293	4	ND	4
		Total Sites in the Lake Mead Dataset		**310**

Sources: Lake Mead NRA staff; Tremblay et al. 2024b; Winslow, et al. 2024
Notes:

- ND = no data available; site counts for elevations below 1,081 feet were lacking for the non-NPS dataset.
- Lake Mead NRA staff provided updated NPS site counts by elevation in March 2026, acknowledging that the park's database may contain errors. For this reason, non-NPS data acquired in August 2023 for the Class I records search have been retained for analysis. Therefore, this table does not correlate with the NPS and non-NPS site counts (or the total number of sites) identified by the Class I records search.
- Survey coverage at Lake Mead is calculated to be 2.8 percent of the area below full pool meaning the number of sites in the Lake Mead data set represents a fraction of the total number of sites present.

There are no NRHP-listed or NRHP-eligible built environment resources within the elevation range for Lake Powell (3,700–3,490 feet), but there is one NRHP-eligible district within the elevation range for Lake Mead (1,221–950 feet): the Echo Bay Developed Area in Lake Mead NRA. The historic-era boat ramp within the district boundary falls between 1,221 and 1,100 feet.

Lake Powell

This section references **Figure TA 3-6** in **Section TA 3.2.1**, Issue 1, and **Table TA 3-3** and **Table TA 3-4** at the end of **TA 3**, Hydrologic Resources.

The following discussion uses the known number of sites within the Lake Powell dataset provided by NPS staff. Survey coverage at Lake Powell is calculated to be 3.3 percent of the area below full pool, meaning the number of sites in the Lake Powell dataset represents a fraction of the total number of sites present.

In general, where water-level elevations are at the top of the Glen Canyon Dam spillway (3,700 feet), all 857 archaeological sites in the Lake Powell dataset would be inundated, while water levels dropping to minimum power pool could expose up to all 857 archaeological sites (depending on how many of those in the Lake Powell dataset remain above 3,490 feet), leaving them vulnerable to impacts. A total of 442 sites (equating to around 52 percent of the sites in the Lake Powell dataset) are below 3,500 feet; thus, where any of the modeled scenarios result in reservoir levels below this elevation, a greater proportion of archaeological sites would be left vulnerable to impacts. Additionally, it is important to note that because some areas at Lake Powell have not been surveyed, any of the modeled scenarios have the potential to impact undiscovered archaeological resources. Based on these parameters, this section will focus on median and interquartile elevations for analysis as presented in **TA 3**, Hydrologic Resources, where appropriate.

As presented in **Table TA 3-3** and **Table TA 3-4** at the end of **TA 3**, Hydrologic Resources, the CCS Comparative Baseline and the No Action, Basic Coordination, Enhanced Coordination, and Maximum Operational Flexibility Alternatives all perform similarly under the Wet Flow Category with minimum WY median elevations around or just below 3,670 feet and EOWY median elevations around 3,680 feet. Therefore, based on these median elevations, any of these modeled scenarios could expose at least 66 archaeological sites, as well as any undiscovered sites that may be present above the EOWY median within the 3,680-3,660-foot zone. The Supply Driven Alternative (both Lower Basin [LB] Priority and LB Pro Rata approaches) has a minimum WY median elevation around 3,640 feet, which could potentially expose up to 138 sites above this elevation while up to 106 sites could be exposed (impacting 32 fewer sites) relative to an EOWY median elevation of around 3,660 feet. The Representative Preferred Alternative has a minimum WY median elevation of around 3,650 feet, which could potentially expose at least 106 archaeological sites and any additional sites above this elevation within the 3,660–3,640-foot zone along with any undiscovered sites that may be present. The EOWY median elevation for the Representative Preferred Alternative at just above 3,660 feet, similar to the same elevation for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), also exposing up to 106 sites above this elevation. Sites exposed at higher elevations may be less vulnerable to impacts from wet-dry cycling and wave action, but may have increased ease of access depending on their location.

As conditions move toward average, the sites affected by wet-dry cycling are found at lower elevations in the lake, while sites exposed at higher elevations would see less of those impacts but may have increased ease of access. In the Average Flow Category, the modeled scenarios begin to perform differently compared to wetter hydrological conditions. Minimum WY median elevations for the CCS Comparative Baseline, and the No Action Alternative fall around and just below 3,550 feet, which could expose at least 316 archaeological sites as well as those above this elevation within the 3,540–3,560-foot zone along with any undiscovered sites that may be present. EOWY median elevations for the CCS Comparative Baseline and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) are around 3,570 feet and just above 3,580 feet for the No Action Alternative under average hydrological conditions. This would leave at least 280 known sites (and any undiscovered sites) present as well as those above 3,570 feet in the 3,580-3,560-foot zone vulnerable to impacts if elevations drop that low. Additional sites would continue to be exposed as water levels drop, depending on elevation (see **Table TA 11-19** above).

For the Average Flow Category, the Basic Coordination Alternative and the Representative Preferred Alternative both perform slightly better with a minimum WY median elevation of around 3,560 feet and around 3,570 feet, respectively, potentially exposing up to 316 sites (and any undiscovered sites present), leaving them vulnerable to impacts. The EOWY median elevation for these two alternatives is higher, around 3,590 feet for the Basic Coordination Alternative and just below 3,600 feet for the Representative Preferred Alternative, potentially leaving at least 249 known sites exposed as well as those above 3,590 feet in the 3,600-3,580-foot zone. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform the best with minimum WY median elevations around 3,610 feet to around, 3,600 feet, respectively, which would expose at between 197 and 249 known sites (and any undiscovered sites). The EOWY median elevations are around 3,630 feet for the Enhanced Coordination Alternative and around 3,620 feet for the Maximum Operational Flexibility Alternative, with the Enhanced Coordination Alternative exposing at least 138 sites (plus any additional sites present above 3,630 feet within the 3,640-3,620-foot zone) and the Maximum Operational Flexibility Alternative exposing up to 197 known sites. Both the Enhanced Coordination and the Maximum Operational Flexibility Alternatives also have the narrowest interquartile ranges for these median elevations (see **Figure TA 3-6** in **TA 3**, Hydrologic Resources).

As hydrological conditions become critically dry, the CCS Comparative Baseline, No Action Alternative, and all action alternatives struggle to reach key elevations for Lake Powell (see **Table TA 3-3** and **Table TA 3-4** at the end of **TA 3**, Hydrologic Resources). For the Critically Dry Flow Category, the CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have flows for minimum WY and EOWY median elevations as well as interquartile ranges that are below 3,490 feet (minimum power pool), dropping down even lower to just below 3,440 feet for the No Action Alternative. Therefore, there is the potential for at least 415 archaeological sites (around 48 percent of the sites in the Lake Powell dataset), along with any undiscovered sites that may be present, to be left exposed and vulnerable under critically dry flow conditions. Additional sites could be left vulnerable as water levels drop below 3,490 feet (minimum power pool), depending on the elevations of the 442 sites recorded below 3,500 feet. As discussed in **Section TA 3.2.1**, Issue 1, in **TA 3**, Hydrologic Resources, the 3,500-foot elevation is important because it provides a 10-foot buffer for water supply and hydropower to stay above minimum power pool. These are also the elevations where sites are vulnerable to wet-dry cycling and wave action would be the lowest for all scenarios because more of the sites would be above the inundation line as water levels drop, but would also have the potential for increased ease of access.

For the Critically Dry Flow Category, the Representative Preferred Alternative fares slightly better with a minimum WY median elevation just above 3,490 feet, which would leave at least 415 sites exposed above 3,500 feet but would protect more sites if they are present above the minimum power pool elevation. The Representative Preferred Alternative performs even better relative to its EOWY median elevation just below 3,510 feet, which would inundate more sites below this elevation in the 3,520-3,500-foot zone. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform better with the minimum WY elevations at around 3,520 feet and 3,510 feet, respectively. EOWY median elevations are higher at around 3,560 feet and around 3,550 feet, respectively. This means that, relative to EOWY median elevations, both alternatives have the

potential to expose at least 316 known sites (and any undiscovered sites present) down to 3,560 feet with the Maximum Operational Flexibility Alternative exposing more sites if any are present above 3,550 feet within the 3,560-3,540-foot zone. The interquartile ranges for the Enhanced Coordination Alternative indicates that this is the only alternative that has the potential to expose the fewest sites of all modeled scenarios relative to critically dry conditions with an that have the potential to expose the fewest sites (up to 249 sites) as the uppermost limit of the EOWY median elevation (75th percentile) for this action alternative reaches around 3,600 feet.

Lake Mead

This section references **Figure TA 3-11** in **Section TA 3.2.1**, Issue 1, and **Tables TA 3-6** and **TA 3-7** at the end of **TA 3**, Hydrologic Resources. Like Lake Powell, this section focuses on median and interquartile elevations for analysis.

The following discussion uses the known number of sites within the Lake Mead dataset provided by NPS staff. Survey coverage at Lake Mead is calculated to be 2.8 percent of the area below full pool meaning the number of sites in the Lake Mead data set represents a fraction of the total number of sites present. For Lake Mead generally, when water-level elevations are at or above 1,221 feet, all 310 archaeological sites in the datasets (and any undiscovered sites present) would be inundated. Conversely, if water levels drop to 950 feet, up to 310 sites in the Lake Mead datasets (and any undiscovered sites above this elevation) would be exposed, depending on the elevations of sites below 961 feet (see **Table TA 11-20**). The archaeological sites recorded at Lake Mead are distributed relatively evenly across the uppermost elevation ranges of the reservoir, with 275 sites (around 89 percent of sites in the Lake Mead datasets) recorded above 1,081 feet. Therefore, if any of the modeled scenarios result in reservoir levels below 1,081 feet, a greater proportion of archaeological sites would be exposed. However, sites exposed at higher elevations may be less vulnerable to impacts from wet-dry cycling and wave action, but they may have increased ease of access depending on their location.

To reiterate, very little of Lake Mead was surveyed prior to the construction of the Hoover Dam in the early 1930s; as a result, undiscovered archaeological resources are likely to be present in unsurveyed areas that could be affected under any of the modeled scenarios.

Although Wet Flow Category conditions as modeled for Lake Mead are less likely to occur based on conditions in recent years, the CCS Comparative Baseline and No Action Alternative perform similarly for minimum CY and EOCY median elevations and interquartile ranges. As presented in **Table TA 3-6** and **Table TA 3-7** at the end of **TA 3**, Hydrologic Resources, even under the wettest hydrological conditions for the modeled scenarios, elevations for the CCS Comparative Baseline and No Action Alternative for both the minimum CY and EOCY median scenarios are between around 1,150 feet and 1,100 feet, exposing between 196 and 265 known archaeological sites and any undiscovered sites at or above these median elevations.

For the Basic Coordination Alternative in the Wet Flow Category, the minimum CY and EOCY median elevations are around 1,170 feet and 1,180 feet, respectively, exposing a minimum of 142 known sites and any undiscovered sites present above these elevations. The Enhanced Coordination and Maximum Operational Flexibility Alternatives perform better, with median elevations around

1,200 to 1,210 feet for both minimum CY and EOCY elevations. This would expose up to 85 known sites (and any undiscovered sites) present down to 1,200 feet; fewer sites would be exposed as water levels rise (see **Table TA 11-20** above). The Representative Preferred Alternative performs similarly, with a minimum CY median elevation of just below 1,200 and an EOCY median elevation of around 1,210 feet under the wettest conditions, potentially exposing the same number of known sites (and any undiscovered sites present) as the Enhanced Coordination and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs only slightly better compared to all the modeled scenarios in this flow category, with minimum CY and EOCY median elevations above 1,210 feet, which would expose fewer than 85 sites depending on their elevations within the 1,221-1,201-foot zone. As mentioned above for Lake Powell, sites exposed at higher elevations at Lake Mead may be less vulnerable to impacts from wet-dry cycling and wave action, but at the same time they may have increased ease of access depending on their location.

In the Average Flow Category, the modeled scenarios result in a variable range of performance respective to minimum CY and EOCY median elevations (refer to **Table TA 3-6** and **Table TA 3-7** at the end of **TA 3**, Hydrologic Resources). The No Action Alternative performs the poorest with median values for both minimum CY and EOCY elevations just below 970 feet and just below 980 feet, respectively, which would expose at least 301 known archaeological sites in the Lake Mead dataset as well as those below this elevation in the 981–961-foot zone (including any undiscovered sites that may be present). The CCS Comparative Baseline has higher median elevations than the No Action Alternative, with a minimum CY median elevation of 1,030 feet and an EOCY median elevation of around 1,040 feet, but it would still leave a minimum of 286 archaeological sites and any additional undiscovered archaeological sites present vulnerable from exposure.

Under average flow conditions, the Basic Coordination Alternative has minimum CY median elevation just above 1,050 feet and EOCY median elevation of just above 1,060 feet, leaving at least 280 archaeological sites (along with any undiscovered sites present) exposed, while the corresponding interquartile ranges from 1,130 feet at the upper limit down to around 1,000 feet could leave, at a minimum, between 227 to 296 known sites (and any undiscovered sites) left vulnerable to impacts from exposure, depending on elevation. The Representative Preferred Alternative performs slightly better with a minimum CY median elevation of just above 1,090 feet and a EOCY median elevation just above 1,100 feet, exposing at least 265 known archaeological sites as well as any undiscovered sites present. Additional sites would be exposed as water levels drop (refer to **Table TA 11-20** above). Additionally for the Average Flow Category, the Enhanced Coordination Alternative has a minimum CY median elevation around 1,100 feet and an EOCY median elevation of around 1,110 feet, which has the potential to at least 245 sites and up to 265 sites (and any undiscovered sites present) depending on elevation. The interquartile range for this alternative is similar for both minimum CY and EOCY elevations, from around 1,130 feet to around 1,060 feet, and around 1,140 feet to around 1,070 feet, respectively, which may expose at least 227 known sites above 1,140 feet and up to 280 known sites (and any undiscovered sites present in the study area at Lake Mead), depending on elevation. The Maximum Operational Flexibility Alternative has a minimum CY median elevation of just below 1,120 feet and an EOCY median elevation of just below 1,130 feet, potentially exposing at least 227 known sites and up to 245 known sites, along with

any undiscovered sites present. The interquartile range for the Maximum Operational Flexibility Alternative is the largest of all modeled scenarios for both minimum CY and EOCY elevations, from around 1,180 feet, leaving up to 142 known sites exposed, down to just above 1,040 feet, which would leave up to 286 archaeological sites (and any undiscovered sites present) vulnerable to impacts.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs the best in the Average Flow Category. The Supply Driven Alternative (LB Priority approach) minimum CY and EOCY median elevations of around 1,140 feet and 1,150 feet, respectively, would expose between 196 known sites up to 227 sites as well as any undiscovered sites present in those elevation ranges. The Supply Driven Alternative (LB Pro Rata approach) has a minimum CY median elevation of just above 1,150 feet and an EOCY median elevation of 1,160 feet, which has the potential to expose at least 196 known sites (and any undiscovered sites) down to 1,160 feet as well as those present above 1,150 feet within the 1,161-1,141-foot zone, leaving them vulnerable to impacts. The interquartile ranges for the Supply Driven Alternative vary, with the range for the LB Pro Rata approach performing the best from just below 1,190 feet (75th percentile) down to just below 1,070 feet (25th percentile) and around 1,180 feet (75th percentile) down to just below 1,060 feet (25th percentile for the LB Priority approach. This has the potential to leave (at minimum) between 85 and 275 known sites vulnerable to exposure under the LB Pro Rata approach and (at minimum) between 142 and 280 known sites exposed under the LB Pro Rata approach (and any undiscovered sites present) during average hydrological conditions.

As conditions grow drier, the modeled scenarios remain the same in relation to one another relative to minimum CY and EOCY median elevations, but they shift downward collectively in elevation about 100 feet in the Critically Dry Flow Category. As discussed in **Section TA 3.2.1**, Issue 1, in **TA 3**, Hydrologic Resources, the 975-foot elevation is important for Lake Mead because it provides a 25-foot buffer for water supply and hydropower to stay above minimum power pool. Like Lake Powell, as conditions for Lake Mead become drier, the sites affected by wet-dry cycling are found at lower elevations in the lake, while sites exposed at higher elevations would see less of those impacts but may have increased ease of access.

Under critically dry hydrological conditions, the elevation where sites are vulnerable to wet-dry cycling and wave action would be the lowest for all scenarios. The CCS Comparative Baseline has a minimum CY median elevation of around 930 feet, while the No Action Alternative drops to around 900, both of which are well below minimum power pool (950 feet). The EOCY median elevation for the CCS Comparative Baseline is around 960 feet; with the No Action Alternative EOCY median elevation dropping below that to around 930 feet. Both would potentially leave all 310 archaeological sites in the Lake Mead datasets (and any undiscovered sites present) vulnerable from exposure, depending on the elevations of the four sites below 961 feet. For the Critically Dry Category, the Basic Coordination Alternative fares slightly better with a minimum CY median elevation of just above 970 feet and an EOCY median elevation of around 980 feet. The Representative Preferred Alternative performs slightly better with a minimum CY median elevation of around 980 feet and an EOCY median elevation of just above 990 feet. Despite having slightly higher median elevations, these two action alternatives still have the potential to leave a minimum of 296 known archaeological sites (over 95 percent of sites in the Lake Mead dataset) and any

undiscovered sites present) exposed during critically dry conditions. The Enhanced Coordination Alternative, which has minimum CY and EOCY median elevations of around or just above 1,000 feet and interquartile ranges from 1,050 feet down to around 950 feet, would have the potential to leave up to all 310 known sites (and any undiscovered sites) exposed, depending on the elevations of the four known sites (and any undiscovered sites present) below 961 feet. The Maximum Operational Flexibility Alternative has similar median elevations of just above 1,010 feet down to around 1,000 feet, which would still leave between 291 and 296 known sites vulnerable to impacts. The interquartile ranges for this alternative are from around 1,060 feet down to around 970 feet, potentially exposing (at minimum) between 280 and 301 known sites at or above 981 feet as well as those down to 970 feet if any of the four known archaeological sites (and any undiscovered sites) in the 981–961-foot zone are present above that elevation.

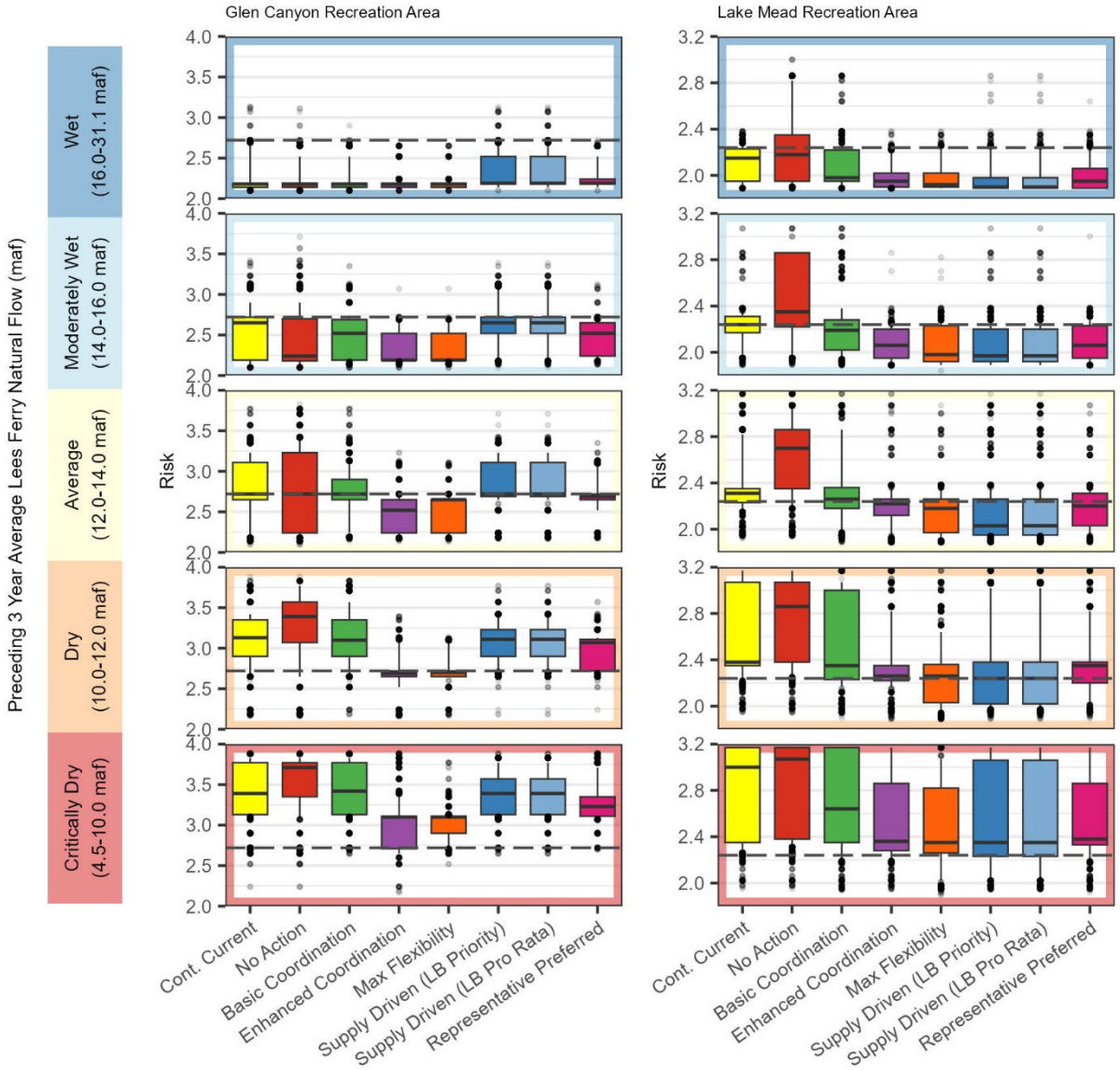
The LB Priority approach under the Supply Driven Alternative has similar minimum CY and EOCY median elevations of around 1,010 feet, while the Supply Driven Alternative (LB Pro Rata approach) has median elevations at or just below around 1,030 feet, the latter of which is the highest median elevation for any of the modeled scenarios in the Critically Dry Flow Category. Regardless of this, a minimum of 286 to 291 known sites (and any undiscovered sites) have the potential to be exposed based on median elevations under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) does have the potential to protect some sites through inundation when examining the upper limits of their interquartile ranges for both minimum CY and EOYC median elevations, which are at or just above 1,070 feet for the LB Priority approach (exposing at least 275 known sites) and around 1,090 feet for the LB Pro Rata approach (exposing at least 265 sites); however, both scenarios would still leave at least 85 percent of the sites in the Lake Mead dataset, in addition to any undiscovered sites present, exposed above the water level and thus vulnerable to impacts.

For the Echo Bay Developed Area, modeled scenarios with minimum CY and EOCY median elevations below 1,100 feet expose additional portions of the boat ramp; however, this would occur outside the NRHP-eligible district boundary toward the receding lakeshore. Conversely, modeled scenarios with elevations above 1,100 feet could partially inundate the ramp, with full submersion occurring at higher elevations along the ramp, which extends up to approximately 1,221 feet. These conditions would be more likely under the Supply Driven Alternative, as the interquartile ranges for minimum CY and EOCY elevation for the LB Priority approach extends to around 1,090 feet. Reservoir elevations exceeding 1,221 feet, would begin to impact recreation area infrastructure within the district boundary.

Preservation Risk Modeling

Preservation risk modeling results were compared to the 90th percentile values of modeled values for WY 2008 to 2025 (i.e., the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead [2007 Interim Guidelines] period); the 90th percentile risk value for Lake Powell is 2.72 and for Lake Mead is 2.24 (Caster et al. 2026). If preservation risk exceeds these threshold values, impacts on archaeological sites may occur at levels beyond those expected under historical conditions for the specific reservoir. For the purposes of this analysis, "historical conditions" coincide with the 2007 Interim Guidelines period (WY 2008–2025). **Figure TA 11-1** shows the WY maximum archaeological preservation risk for Lake Powell and Lake Mead.

Figure TA 11-1
Water Year Maximum Archaeological Preservation Risk at Glen Canyon NRA and Lake Mead NRA



For both Lake Powell and Lake Mead, the WY maximum preservation risk median is lowest in the Wet Flow Category for the CCS Comparative Baseline, No Action Alternative, and all action alternatives. The median for Lake Powell is 2.18 for all except for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Representative Preferred Alternative, which are slightly higher at 2.19. All the median risk values remain below 2.72 during wet flow periods for Lake Powell, meaning that impacts on archaeological sites, if they occur, would like those anticipated under similar historical conditions. At Lake Mead, the median risk value in the Wet Flow Category is at or below 2.0 for all alternatives (including the Representative Preferred Alternative at 1.95), except for the No Action Alternative at 2.18 and the CCS Comparative Baseline at 2.15. None of the

median risk values are above 2.24 for Lake Mead, which means impacts to archaeological sites, if they occur, would not be at levels greater than expected under similar historical conditions. However, the interquartile range for the No Action Alternative does reach up to 2.35 (75th percentile), the highest of any of the modeled scenarios.

In the Average Flow Category, the CCS Comparative Baseline, and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have preservation risk median values at the 2.72 threshold for Lake Powell. The Representative Preferred Alternative has a median value of 2.69, followed by the Maximum Operational Flexibility Alternative at 2.65 and the Enhanced Coordination Alternative at 2.52. The preservation risk median for the Enhanced Coordination Alternative is 2.52 and for the Maximum Operational Flexibility Alternative at 2.65; both have the same interquartile ranges from 2.65 to 2.24 under average hydrological conditions. The Representative Preferred Alternative has the narrowest interquartile range from 2.72 (75th percentile) to 2.65 (25th percentile) while the No Action Alternative has the greatest variation in risk in the interquartile range from 3.23 (75th percentile) down to 2.24 (25th percentile). Therefore, under average flow periods as modeled, if impacts on archaeological sites occur, they would not be at levels beyond those otherwise expected under similar average conditions historically.

For Lake Mead in the Average Flow Category, the preservation risk median value is highest for the No Action Alternative at 2.70. The CCS Comparative Baseline is the second highest at 2.31 while the Basic Coordination Alternative is at 2.26, which remains above the preservation risk value threshold of 2.24. This means that, during average flows, the risk to archaeological sites is greater than would otherwise be expected under similar historical conditions. The Enhanced Coordination Alternative has a preservation risk median of just below 2.24 at 2.22 followed by the Representative Preferred Alternative at 2.20 and the Maximum Operational Flexibility Alternative at 2.18. The interquartile ranges for the CCS Comparative Baseline, the No Action Alternative as well as all the action alternatives have upper preservation risk values above 2.24, including the Representative Preferred Alternative at 2.31. The lower extent of these interquartile ranges drops below 2.24 except for the No Action Alternative, which remains above it at 2.35 in the Average Flow Category. The median risk value for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the lowest at 2.03.

In the Critically Dry Flow Category for Lake Powell, the preservation risk median values for CCS Comparative Baseline and all the alternatives are over the 2.72 threshold. The No Action Alternative has the median highest preservation risk for Lake Powell, which is well over 2.72 at 3.71, followed by the Basic Coordination Alternative at 3.42, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative at 3.39. The Representative Preferred Alternative has a preservation risk median value of 3.23 while both the Maximum Operational Flexibility and Enhanced Coordination Alternatives have at 3.10; however, the interquartile range of the Enhanced Coordination drops to 2.71. Again, the lower the preservation risk value, the better the performance and where these median values fall below 2.72 at Lake Powell, impacts to archaeological sites, if they occur, would not be beyond those anticipated under similar historical conditions.

The preservation risk median values for Lake Mead in the Critically Dry Flow Category for all scenarios are well above the 2.24 preservation risk value threshold. The No Action Alternative performs the worst at 3.07 followed by the No Action Alternative at 3.0. All of the action alternatives thus fall below 3.0, with the Basic Coordination Alternative at 2.64, the Representative Preferred Alternative at 2.38, the Enhanced Coordination Alternative at 2.36, and the Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives at 2.35. Because neither the CCS Comparative Baseline, the No Action Alternative, nor the action alternatives have preservation risk median values below 2.24, impacts to archaeological sites would be at levels beyond those anticipated under critically dry conditions historically.

Figure TA 11-2 and **Figure TA 11-3** compare alternatives by showing the percentage of futures in which the preservation risk is below 2.72 for Lake Powell and 2.24 for Lake Mead in at least 90 percent of months. The 2.72 and 2.24 preservation risk values represent the 90th percentile of modeled historical values for WY 2008–2025 (the 2007 Interim Guidelines period), which includes the period of significant reservoir storage loss. To reiterate, if preservation risk exceeds these value thresholds for the reservoirs, impacts on archaeological sites may occur at levels greater than those expected under historical conditions. The highlighted row shows the percentage of futures at that preferred minimum performance.

Figure TA 11-2
Cultural Resources in Glen Canyon NRA: Robustness
Percentage of futures in which monthly preservation risk stays below the value specified in each row in at least 90 percent of months

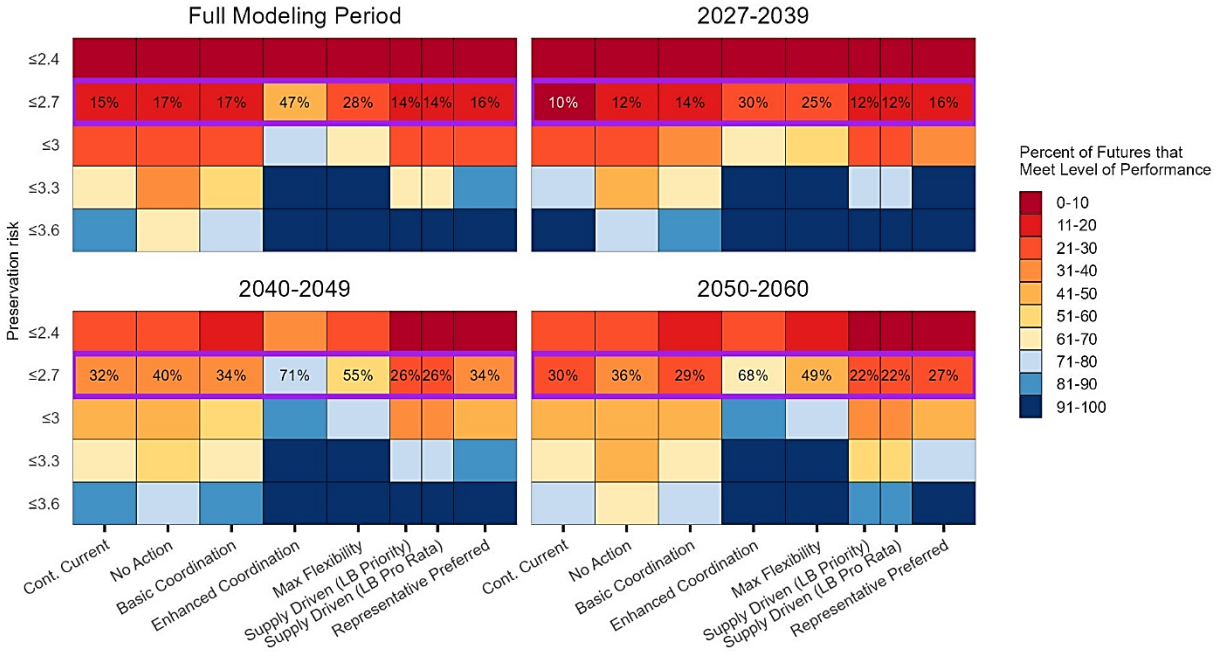
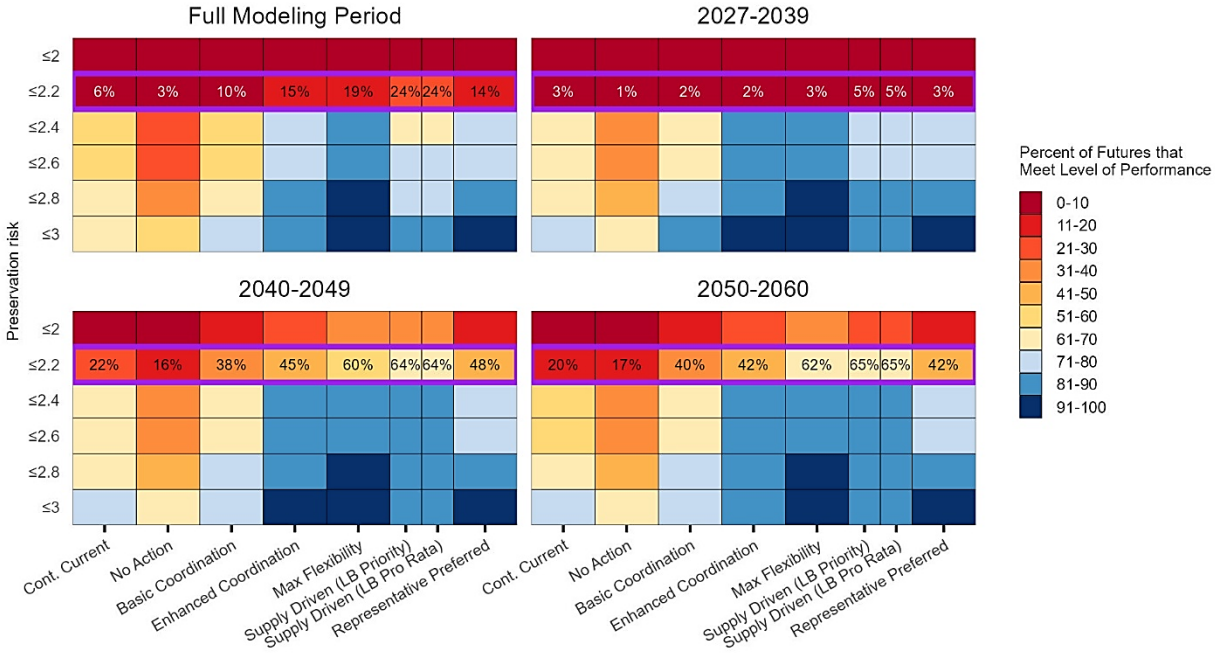


Figure TA 11-3
Cultural Resources in Lake Mead NRA: Robustness
Percentage of futures in which monthly preservation risk stays below the value specified in each row in at least 90 percent of months



For Lake Powell, over the full modeling period, the Enhanced Coordination Alternative is the most robust, meeting the 2.72 risk threshold in 47 percent of futures. The Maximum Operational Flexibility Alternative is less robust, meeting the 2.72 threshold in 28 percent of futures, followed by the No Action and Basic Coordination Alternatives at 17 percent, the Representative Preferred Alternative at 16 percent, and the CCS Comparative Baseline at 15 percent. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meets the preferred level of performance in 14 percent of futures. This relational pattern is consistent if the full modeling period is broken out into shorter periods, including the first decadal period from 2027–2039 where the Enhanced Coordination Alternative also performs the best at 30 percent whereas the CCS Comparative Baseline performs the worst at 10 percent. It is important to note that 2027, as the beginning of the first 10-year interval, is anticipated to have low reservoir elevations and, therefore, the modeling for this breakout (2027–2039) shows very low percentages of futures met for the preferred minimum of performance across the CCS Comparative Baseline, the No Action Alternative, and all other action alternatives. See **Figure TA 11-2** above for robustness modeled for 2040–2049 and 2050–2060 at Lake Powell.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust by meeting the 2.24 risk threshold in 24 percent of futures over the full modeling period. The CCS Comparative Baseline and No Action Alternative meet the preferred minimum of performance in only 6 and 3 percent of futures, respectively. The Maximum Operational Flexibility Alternative meets the threshold in 19 percent of futures, followed by the Enhanced Coordination

Alternative at 15 percent, the Representative Preferred Alternative at 14 percent, and the Basic Coordination Alternative at 10 percent. If the modeling period is broken out, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) can be seen to meet the threshold for only 5 percent of futures in the first decadal period (2027–2039), followed by the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative, and the Representative Preferred Alternative, all three of which meet the preferred level of performance in only 3 percent of futures. The Basic Coordination and Enhanced Coordination Alternatives meet the threshold 2 percent of the time while the No Action Alternative is at 1 percent for the 2027–2039 modeling period. It is important to note that, when examining the first decadal period (2027–2039) at Lake Mead, the percentage of futures meeting the preferred minimum of performance drops drastically because the anticipated water levels for Lake Mead in 2027 are expected to be low. Therefore, the robustness modeling shows a substantial drop in performance compared to the full modeling period. See **Figure TA 11-3** above for robustness modeled for 2014–2049 and 2050–2060 at Lake Mead.

Overall, the Enhanced Coordination Alternative is the most robust for Lake Powell for the full modeling period and the first decadal modeling period (2027–2039), followed by the Maximum Operational Flexibility Alternative. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust for, followed by the Maximum Operational Flexibility Alternative for the full modeling period. Looking at only the 2027–2039 modeling period, while the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) still remains the most robust at 5 percent, the CCS Comparative Baseline, Representative Preferred Alternative, and Maximum Operational Flexibility Alternative are all equally, but lesser, robust for the first 10-year period at 3 percent.

River Flows

This section references the discussion presented in **Section TA 3.2.4**, Issue 4, as presented in **TA 3**, Hydrologic Conditions, with additional references to other sections as appropriate.

For the purposes of analyzing potential impacts related to changes in river flow, archaeological sites that may be physically affected are those located along or immediately adjacent to the river, where erosion caused by moving water may occur. As with the lake site data discussed above, variable survey coverage and older locational data must be taken into account. To identify a representative number of sites that may be affected by changes in flow, sites with all or portions of their boundaries in the river corridor or within 20 meters (66 feet) of the river corridor (bank to bank) were identified from the overall datasets using a geographic information system. **Table TA 11-21** lists the number of sites along the river.

Like archaeological sites, built environment resources, and specially designated cultural resources that may be most affected by river flow changes are those immediately along the river corridor. As previously mentioned, built environment resources along the river tend to be more resilient to changes in river flow because they were designed to avoid impacts from shifts in conditions. Using elevations from DEM and other data sources, NRHP-listed and NRHP-eligible built environment resources and specially designated cultural resources that are all or in part within 20 meters (66 feet) of the riverbank and/or above the river itself (such as in the case of bridges) were identified.

Unevaluated built environment resources are treated as eligible for the purposes of analysis. **Table TA 11-22** summarizes these properties.

Table TA 11-21
Representative Number of Sites within 20 Meters (66 Feet) of the River by Reach

Reach	No. of NPS Sites	No. of Sites (non-NPS)	Total
Glen Canyon Dam to Lake Mead	128	43	171
Hoover Dam to Davis Dam	180	78	258
Davis Dam to Parker Dam	N/A	64	64
Parker Dam to Imperial Dam	N/A	16	16
Imperial Dam to the SIB	N/A	2	2

Source: Eddy et al. 2024; Eskenazi 2024; Tremblay et al. 2024b; Winslow et al. 2024
Note: The information presented in this table incorporates NPS and non-NPS data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Table TA 11-22
Built Environment and Specially Designated Cultural Resources within 20 Meters (66 Feet) of the River by Reach

Reach	Resource Name	Status	Property Type
Glen Canyon Dam to Lake Mead	Lee's Ferry and Lonely Dell Historic District	NRHP (Listed)	District
Hoover Dam to Davis Dam	Willow Beach Gauging Station	NRHP (Listed)	Structure
Davis Dam to Parker Dam	Historic U.S. Route 66	NRHP (Listed)	Structure
	National Old Trails Arch Bridge (Topock Bridge)	NRHP (Listed)	Structure
Parker Dam to Imperial Dam	Fisher's Landing	Unevaluated	District
Imperial Dam to the SIB	Southern Pacific Railroad Bridge	Unevaluated	Structure
	Ocean-to-Ocean Highway Bridge	NRHP (Listed)	Structure
	Yuma Crossing and Associated Sites	NHL, NRHP (Listed)	District

Source: Eddy et al. 2024; Eskenazi 2024; Tremblay et al. 2024b; Winslow et al. 2024
Notes: The Hoover Dam to Davis Dam and Davis Dam to Parker Dam reaches exclude Lake Mohave and Lake Havasu, respectively, because these two reservoirs would continue to be operated under their same rule curves for target end-of-month elevations, regardless of modeled scenario. The information presented in this table incorporates data acquired in August 2023 for the Class I records search; therefore, the number of sites and/or their corresponding NRHP status do not reflect current agency databases.

Glen Canyon Dam to Lake Mead

This section references the median and interquartile WY release volumes (in maf) from Glen Canyon Dam illustrated in **Figure TA 3-21** in **Section TA 3.2.3**, Issue 3, with the full statistical

summary presented in **Table TA 3-14** at the end of **TA 3**, Hydrologic Resources. In all categories except the Critically Dry Flow Category, the high end of the results range has been cut off to improve comparisons in the average and drier flow conditions.

Since 2008, WY release volumes from Glen Canyon Dam have been from around 7.0 maf to around 12.5 maf, averaging around 8.7 maf. The annual average release of around 8.7 maf is just over 1.0 maf lower than the average annual releases from 1996 to 2007 of 9.8 maf, which is the result of both hydrologic conditions in the Colorado River Basin and operations under the 2007 Interim Guidelines (see **Section TA 3.1.3**, Lake Powell and Glen Canyon Dam, in **TA 3**, Hydrologic Resources). In general, WY releases from Glen Canyon Dam deviate that fall outside the historical range of around 7.0–12.5 maf have greater potential to impact known cultural resources within 20 meters (66 feet) of the river as well as to undiscovered resources that may be present along the river corridor. In addition, higher WY release volumes can increase erosion along the river corridor, even when releases remain in this historical range. As stated above, impacts from changes in river flow would include water erosion from river currents during higher releases, but may also include exposure from lower water levels where dam release volumes are reduced; however, these impacts are only be considered in terms of this analysis when these volumes are outside past releases or flows.

River flows from Lake Powell to Lake Mead primarily consist of controlled releases from Glen Canyon Dam. WY releases from Glen Canyon Dam under the Wet Flow and Average Flow Categories would generally fall within the range of past annual release volumes for all modeled scenarios. Under wet flow conditions, the median volumes of WY releases range from around 8.4 maf for the CCS Comparative Baseline up to 12.0 maf for the Representative Preferred Alternative. Neither the CCS Comparative Baseline, No Action Alternative, nor the action alternatives (including the Representative Preferred Alternative) have median volumes that fall below 7.9 maf in the Average Flow Category. In terms of interquartile ranges under wetter hydrological conditions, none of the modeled scenarios exceed past release volumes (7.0–12.5 maf). For sites within 20 meters (66 feet) of the river in this reach, it is anticipated that, under wetter conditions, there would be no additional impacts because none of the modeled scenarios deviate outside the established range. This is also true for the one NRHP-listed built environment resource found along this reach because the boundary of the Lees Ferry and Lonely Dell Historic District extends into the river channel.

For the Average Flow Category, the interquartile range for the Enhanced Coordination Alternative is the only modeled scenario that has the potential to deviate the most from the range of past release volumes (7.0 maf up to 12.5 maf), as it is modeled as potentially dropping to around 6.9 maf (25th percentile). Reductions in the volume of WY releases would affect river flows, thereby potentially exposing the Steamboat Charles Spencer. The same drops in river flows, resulting from reduced WY releases from Glen Canyon Dam, would not be detrimental to the only known historic property within 20 meters (66 feet) of the river, as lower water levels would protect the Lee's Ferry and Lonely Dell Historic District from river currents.

For the Critically Dry Flow Category, median WY release volumes for the CCS Comparative Baseline, No Action Alternative, and all action alternatives (including the Representative Preferred Alternative) fall below 7.0 maf, down as low as around 5.1 maf for the Enhanced Coordination

Alternative. Under the critically dry hydrological conditions, the No Action Alternative performs better than the others relative to the upper limits of the interquartile range (75th percentile), which is 8.2 maf, followed by the CCS Comparative Baseline at around 7.7 maf. The Representative Preferred Alternative has one of the narrowest interquartile ranges under critically dry hydrological conditions, with an upper limit around 6.0 maf, which is still below the bottom of the range of past flow volumes at 7.0 maf. All the modeled scenarios could expose the Steamboat Charles Spenser if the reduced volumes of these WY releases cause the river to drop below previous water levels. On the other hand, these same potential drops in river water level would protect the only NRHP-listed property within 20 meters (66 feet) of the river (the Lee's Ferry and Lonely Dell Historic District), as previously discussed.

Hoover Dam to Davis Dam

This section references the median and interquartile CY release volumes from Hoover Dam illustrated in **Figure TA 3-25** in **Section TA 3.2.3**, Issue 3*,* with the full range of statistical data presented in **Table TA 3-19** at the end of **TA 3**, Hydrologic Resources. In all categories, the high end of the results range has been cut off to improve comparisons in the average and drier flow conditions.

Since 2008, CY releases from Hoover Dam have been from around 8.5 maf to around 9.6 maf, averaging around 9.2 maf (see **TA 3.1.7**, Hoover Dam to Lake Mohave*,* in **TA 3**). Since the implementation of the 2007 Interim Guidelines, releases from Hoover Dam have decreased to meet monthly elevation targets, resulting in lower river flows through this reach. The 2007 Interim Guidelines have reduced average CY releases from Hoover Dam by approximately 1.0 maf (averaging 9.2 maf). In general, CY releases from Hoover Dam occurring outside the historical range of around 8.5–9.6 maf have greater potential for impacts on known cultural resources within 20 meters (66 feet) of the river as well to undiscovered resources that may be present along the river corridor. The impacts from changes in river flow would include water erosion from river currents during higher releases, but may also include exposure from lower water levels where dam release volumes are reduced; however, these impacts are only considered in terms of this analysis when these volumes are outside past releases that in turn change river flows. Based on these parameters, this section will focus on median and interquartile release volumes (in maf) for analysis and frequently refers to **TA 3**, Hydrologic Resources, where appropriate.

River flows below Lake Mead primarily consist of controlled releases from Hoover Dam. Median CY releases under the Wet Flow Category would remain within the range of past volumes except for the Supply Driven Alternative, with the LB Priority approach around 10.2 maf and the LB Pro Rata approach around 10.4 maf. Under this alternative, the median CY release volumes would exceed 9.6 maf by up to 0.8 maf, potentially causing erosion to sites along the river. Interquartile ranges for the CCS Comparative Baseline and the No Action Alternative are narrow, with the upper range (75th percentile) for both exceeding past CY release ranges at around 10.1 maf while the lower range (25th percentile) stays within past conditions. Similarly for the action alternatives, while the interquartile ranges vary, the upper limits (75th percentile) of all (including the Representative Preferred Alternative) exceed CY releases of 9.6 maf with the LB Pro Rata approach under the Supply Driven Alternative being the highest at around 11.4 maf. Exceeding the range of past CY release volumes (i.e., above 9.6 maf) risks impacting archaeological sites within 20 meters (66 feet) of the river that

have not been previously affected by river flows if releases from Hoover Dam that are above 9.6 maf cause river water levels to also rise within this reach. Depending on these river levels, the substructure of the one NRHP-listed built environment resource (Willow Beach Gaging Station) identified within this reach could be affected, but this structure was designed to withstand changes in historical river flows and was built directly above the river's surface; therefore, impacts are unlikely even under the wet hydrological conditions presented under the different modeled scenarios.

For the Average Flow Category, median CY release volumes for the No Action Alternative is the only modeled scenario that remains within the 8.5–9.6 maf range for previous release volumes below Hoover Dam in this reach at around 8.6 maf. The CCS Comparative Baseline falls just under previous release volumes at around 8.3 maf. The action alternatives do not perform as well, with the median CY release volume for the Basic Coordination Alternative in the Average Flow Category around 8.0 maf, followed by the Representative Preferred Alternative at around 7.9 maf, the Maximum Operational Flexibility Alternative at around 7.8 maf, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) at around and just below 7.7 maf, and the Enhanced Coordination Alternative at just below 7.6 maf. Where impacts on archaeological sites result from erosion caused by moving water, these may be less likely to occur if the reduced CY release volumes cause the river to drop below previous water levels. The same drops in river water levels below Hoover Dam would not be detrimental to NRHP-listed Willow Beach Gaging Station.

For the Critically Dry Flow Category, median CY release volumes would be well below previous volume ranges (i.e., below 8.5 maf) for the CCS Comparative Baseline, No Action Alternative, and all action alternatives, which fall below 8.0 maf, down as low as 6.4 maf for the Maximum Operational Flexibility Alternative, with the Enhanced Coordination Alternative slightly higher at around 6.5 maf. Under the driest hydrological conditions, the No Action Alternative, followed by the CCS Comparative Baseline, performs better than the others relative to the upper limits of their interquartile ranges (75th percentile), which are around 8.6 maf for the No Action Alternative and around 8.3 maf for the CCS Comparative Baseline. The Representative Preferred Alternative has an upper interquartile range limit of around 7.9 maf, which again is below the range past flow volumes (8.5–9.6 maf). Again, relative to impacts to archaeological sites that may be subject to erosion caused by moving water, the modeled scenarios may be less likely to physically affect archaeological sites if the reduced CY release volumes cause the river to drop below previous water levels. Likewise, these same potential drops in river water level would not affect the NRHP-listed Willow Beach Gaging Station previously discussed.

Within this reach is Lake Mohave, which is operated under a rule curve that maintains end-of-month target elevations between 630 feet up to around 646 feet, has been kept relatively constant at around 641 feet since 2008 (see **Section TA 3.1.7**, Hoover Dam to Lake Mohave*,* in **TA 3**, Hydrologic Resources). Because Lake Mohave would continue to be operated under this rule curve, regardless of scenario, there are no anticipated impacts on any known cultural resources around the reservoir in this portion of the reach.

Davis Dam to Parker Dam

The 84-mile-long reach from Davis Dam to Parker Dam forms Lake Havasu. Davis and Parker Dams are operated under the same rule curve that determines end-of-month target elevations, which are between 445 and 450 feet for Lake Havasu (see **Section TA 3.1.8**, Davis Dam to Lake Havasu, in **TA 3**, Hydrologic Resources). Therefore, no impacts from the CCS Comparative Baseline, the No Action Alternative, nor any of the action alternatives (including the Representative Preferred Alternative) to 64 known archaeological sites within 20 meters (66 feet) of the river between Davis Dam and Parker Dam are anticipated. This is also true for the portions of NRHP-listed Historic U.S. Route 66 or the NRHP-listed National Old Trails Bridge (Topock Bridge) as the only two built environment resources within 20 meters (66 feet) of the river.

Parker Dam to Imperial Dam

Parker Dam releases are scheduled on both a daily and hourly basis, and while the 2007 Interim Guidelines did not specifically target operations of this dam, implementation of these guidelines has resulted in reduced annual release rates (see **Section TA 3.1.9**, Parker Dam to Cibola Gage, in **TA 3**, Hydrologic Resources). Parker Dam annual releases since 2008 have ranged from 6.2 maf to 6.7 maf, averaging 6.4 maf, which represents an average annual decrease of 1.0 maf in volume from the previous pre-2008 average of 7.4 maf. At the end of this reach is Imperial Dam and the Imperial Reservoir, which is operated to maintain a nearly constant elevation to meet water delivery requirements for major diversions to California (All-American Canal) and Arizona (Gila Main Canal) (see **Section TA 3.1.10**, Cibola Gage to Imperial Dam, in **TA 3**, Hydrologic Resources). Additionally, this reach is characterized by several stretches of mechanically channelized river corridor (particularly through wildlife refuges) and no impacts on the 16 known archaeological sites or the one built environment resource (Fisher's Landing) within 20 meters (66 feet) of the river are expected regardless of flow volume through these areas.

Imperial Dam to SIB

The Colorado River channel is reinforced by a system of leaves from Imperial Dam south to the Northerly International Boundary (NIB) and flows through this first portion of this reach are influenced primarily by Imperial Dam releases made for water deliveries. Other factors, like the Laguna Dam and the confluence with the Gila River, also influence river flows in this reach. Implementation of the 2007 Interim Guidelines did not affect the operations or flows in the upper portion of the reach between Imperial Dam and the NIB (see **Section TA 3.1.11**, Imperial Dam to Northerly International Boundary, in **TA 3**, Hydrologic Resources). Because of the levee system from Imperial Dam south to the NIB, there are no anticipated impacts on the two archaeological sites, two built environment resources (Southern Pacific Railroad Bridge and the NRHP-listed Ocean-to-Ocean Highway Bridge) or the Yuma Crossing NHL (also NRHP listed) located within 20 meters (66 feet) of the river.

Just downstream of the NIB is Morelos Dam, which impounds most of the water supply to be diverted to the United Mexican States (Mexico), and is owned, operated, and maintained by Mexico per the 1944 United States-Mexico Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande. Most of the remaining Colorado River water supply that makes it to the Morelos Dam is diverted to Mexico via the Reforma Canal. Thus, the remaining river flows below Morelos Dam to the SIB consist of excess water volumes above Mexico's scheduled delivery

due to Flood Control operations at Hoover Dam, seepage from Morelos Dam and other return/inflows. Morelos Dam operations did not change with the implementation of the 2007 Interim Guidelines because of the required 1.5 maf annual water delivery (see **Section TA 3.1.12**, NIB to SIB*,* in **TA 3**, Hydrologic Resources). There are no other known cultural resources (aside from Morelos Dam, which is excluded from analysis) between the lower portion of this reach from the NIB to the SIB.

TA 11.2.3 Issue 2: How will changes in dam operations affect sediment availability for aeolian transport to protect archaeological sites in the Grand Canyon?

As discussed above in **Section TA 11.2.1**, the aeolian transport model looks at favorable conditions for wind-born sand to be present to protect archaeological sites over long periods of time using projected vegetation cover and exposed sand area or sandbar volume (Butterfield and Palmquist 2026; Kelley et al. 2026; Salter and Grams 2026). The vegetation and sandbar volume modeling used is from the Marble Canyon sub-reach from Lees Ferry Gaging Station to the Little Colorado River. The exposed sand modeling was conducted for the portion of the river from Lees Ferry to Bright Angel Creek. While these analyses are limited to those reaches, the results provide general insight into sediment and vegetation responses that may also be relevant to other portions of the river corridor with similar geomorphic and hydrologic conditions.

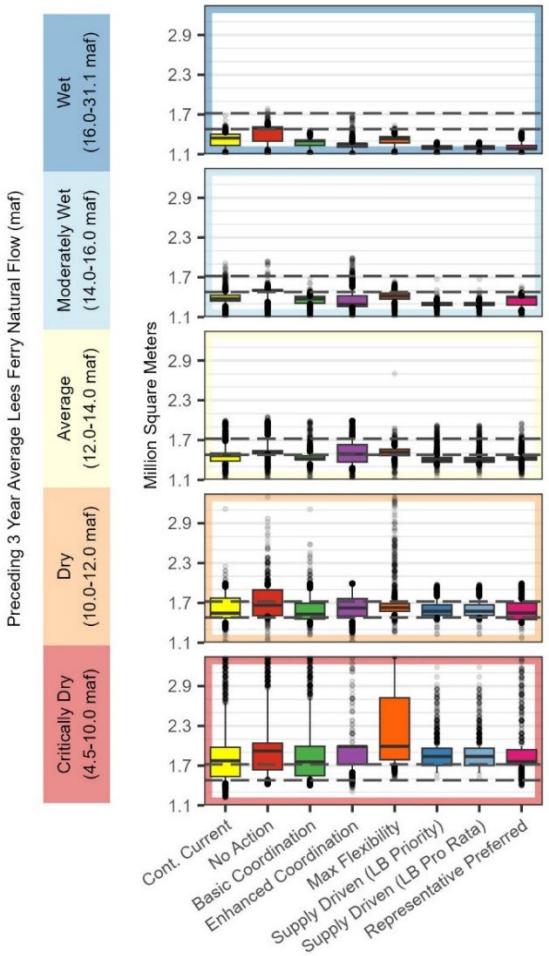
The results of the annual vegetation cover modeling are presented in **TA 9**, Vegetation, Including Special Status Species. Overall, less vegetation is better for aeolian sand transport because it leaves available sand exposed to be picked up by the wind. As discussed in **Section TA 9.2.2**, Issue 1, and seen in **Figure TA 9-14** (see **TA 9**, Vegetation, Including Special Status Species), for all modeled scenarios under the wet and moderately wet conditions, there would be less annual total vegetation cover (below modeled historical conditions, indicated by the dashed line in **Figure TA 9-14**) from higher water levels and longer HFEs. As conditions grow drier, water flows diminish, and HFEs are shorter, annual total vegetation cover thereby increases (see **Figure TA 9-14** in **TA 9.2.2** of **TA 9**, Vegetation, Including Special Status Species). For the Average Flow Category, the median for the CCS Comparative Baseline, the No Action Alternative and all action alternatives (including the Representative Preferred Alternative) is at or just below the modeled historical conditions (i.e., the 2007 Interim Guidelines period [WY 2008–2025]) and the interquartile ranges are relatively small. This indicates that the annual total vegetation may be similar to historical conditions under average flows. Conversely, under the dry and critically dry conditions, annual total vegetation cover increases, and differentiation between alternatives can be seen. For the Critically Dry Flow Category, the medians and interquartile ranges are above the modeled historical conditions (dashed line) for all sub-reaches and all alternatives except the interquartile range for the CCS Comparative Baseline, which drops just below the dashed line (see **Figure TA 9-14** in **TA 9**). This indicates that there may be more annual total vegetation cover, especially under critically dry flows.

The results of the sandbar volume modeling are presented in **TA 5,** Geomorphology and Sediment. As discussed in **TA 5**, for an HFE to be triggered, enough sand needs to be available in Marble Canyon and enough water needs to be available in Lake Powell (as measured by water level), with both the required amounts of sand and water being dependent on the selected HFE duration. Additionally, HFE releases can only be implemented when Lake Powell water levels are at or above

3,500 feet, with sandbar deposition occurring most rapidly during the first 4 days of an HFE event. Lastly, sandbar volume modeling uses the assumption that HFEs are implemented as often as possible (see **TA 5.2.1**, Modeling Criteria and Assumptions). For the aeolian transport model, increased exposed sandbar volume (or the amount of "useable" sand) means more sand is available to protect archaeological sites. In general, as conditions get drier and the amount of water flowing through the river decrease, exposed sandbar volume increases (see **Section TA 5.2.5**, Issue 4, in **TA 5**, Geomorphology and Sediment). Differences in performance among the alternatives also increase as hydrological conditions become drier, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives performing the best for the Critically Dry Flow Category (see **Figure TA 5-12** in **Section TA 5.2.5**).

Figure TA 11-4 shows the results of the WY average of exposed sand area modeling, with the 90th percentile and median (50th percentile) of modeled sand areas depicted as the two dashed lines. As with exposed sandbar volume, increased exposed sand area is beneficial for the aeolian transport of sand to protect archaeological sites. In the Average Flow Category, median exposed sand area is

Figure TA 11-4
Water Year Average of Exposed Sand Area



around the 90th percentile (upper dashed line) and the median (50th percentile, lower dashed line) of modeled sand area (in million square meters). As conditions become drier, all modeled scenarios perform similarly with modeled median exposed sand area above the observed median, with the No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives having slightly higher median values than the CCS Comparative Baseline and the other action alternatives, particularly in the Critically Dry Flow Category. Under critically dry conditions, the Maximum Operational Flexibility Alternative has the most variability with the greatest interquartile range.

Figure TA 11-5 shows the results of the aeolian sand modeling in which the percentage of futures meet one of two criteria: either the annual sand area is greater than the median observed sand area over the last 20 years and the vegetation cover area is less than the median observed area over the last 20 years, or the sandbar volume is greater than 1.5 times the initial condition. The highlighted row shows when those conditions are met at least 1 out of every 3 years, which is the optimal time frame for enough sand to be available for aeolian transport based on previous studies.

Figure TA 11-5
Multi-model Aeolian Transport Condition: Robustness
Percent of futures in which annual sand area is >50th and vegetation cover is <50th percentile or sandbar volume is >1.5 times initial condition in the frequency specified in each row



Over the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust; they meet the preferred minimum of performance in 19 and 18 percent of futures, respectively, followed by the No Action Alternative only in 14 percent of futures. The Basic Coordination Alternative meets the preferred minimum of performance in only 9 percent of futures, with the Representative Preferred Alternative meeting it in only 6 percent of futures. The

Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the least robust, meeting the preferred minimum of performance in only 3 percent of futures with the CCS Comparative Baseline only slightly higher at 4 percent of futures. If the year interval is lengthened (i.e., to 1 out of 4, 5, or 6 years), the models perform in a similar overall pattern with the Enhanced Coordination Alternative performing the best until reaching the 1-out-of-6-year interval when the No Action Alternative performs the best over the full modeling period.

If the modeling period is broken out for the first 10 years, the No Action Alternative performs the best, meeting the preferred minimum performance in 38 percent of futures for the highlighted interval, followed by the Enhanced Coordination Alternative at 35 percent of futures in the first decadal period (2027–2039), followed by the Maximum Operational Flexibility Alternative at 30 percent of futures. The Basic Coordination Alternative and the CCS Comparative Baseline meet the preferred minimum of performance in 18 percent and 19 percent of futures, respectively, followed by the Representative Preferred Alternative at 17 percent. The Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches) performs with only 9 percent of futures meeting the minimum preferred performance. Due to aeolian transport favoring drier conditions because more useable sand is available and the beginning of the first decadal period (2027-2039) is anticipated to have low reservoir elevations, the modeling for this breakout (2027–2039) depicts more modeled futures meeting the preferred minimum of performance across the CCS Comparative Baseline, the No Action Alternative, and all action alternatives than over the full modeling period. See **Figure TA 11-5** above for robustness modeled for 2040–2049 and 2050–2060 relative to multi-model aeolian transport condition.

The overall results seem to indicate an increase in the percentage of futures over time, which may correlate to increased available sand over time; however, the perceived increase is driven by an increase in sandbar volume over time in the modeling with the understanding that HFEs would continue as planned. In reality, the decision to conduct HFEs depends on annual review and the actual HFE frequency may differ from that assumed or predicted in the modeling.

TA 11.2.4 Summary Comparison of Alternatives

Issue 1: How will any changes in dam operations affect (1) lake elevations at Lake Powell and Lake Mead and (2) river flows downstream, which may affect cultural resources?

Lake Powell and Lake Mead

Because the continual inundation of archaeological sites is more conducive to preservation than repeating cycles of inundation and exposure due to the risks of wave action, changes in lake elevations that may expose previously inundated resources is the biggest concern. As water elevations drop, the elevation at which sites become vulnerable to wet-dry cycling and wave action becomes lower; however, while sites exposed at higher elevations may be less vulnerable to impacts from wet-dry cycling and wave action, they may also have increased ease of access depending on their location. Based on the hydrological models, during the wet hydrological conditions, median elevations at Lake Powell are projected to stay around or above 3,640 feet for all modeled scenarios. As conditions become drier, the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform the best in the Average Flow Category, with median water elevations from around 3,600 feet to around 3,630 feet relative to average hydrological conditions. They also

perform best in the Critically Dry Flow Category; however, the projected medians are between 3,510 feet and 3,560 feet for these two action alternatives, potentially leaving (at minimum) between 316 and 381 archaeological sites and any undiscovered sites above these elevations exposed. Under critically dry conditions, the Representative Preferred Alternative has median water levels from just above 3,490 feet (minimum WY), up to just below 3,510 feet (EOWY), which has the potential to leave up to 415 sites exposed above 3,500 feet, but would inundate more sites if they are present above the minimum power pool elevation of 3,490 feet.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs best over in both the Average Flow and Critically Dry Flow Categories, followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) have projected median elevations between 1,140 feet and 1,160 feet under average hydrological conditions, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives have median elevations between 1,100 feet and 1,130 feet, respectively. Higher reservoir levels means that more sites are inundated as opposed to exposed at lower reservoir levels. The Representative Preferred Alternative has median water levels of around 1,080 to 1,090 feet, exposing between 265 and 275 known archaeological sites as well as any undiscovered sites present above these elevations relative to average hydrological conditions. For the Critically Dry Flow Category, all scenarios would result in the exposure of at least 306 archaeological sites (all but four in the Lake Mead dataset) and any undiscovered sites that may be present based on median water levels; however, the LB Pro Rata approach under the Supply Driven Alternative has the potential to expose the fewest number of known sites (286) with median elevations up to around 1,030 feet. The Representative Preferred Alternative has median water levels from around 980 feet to around 990 feet, potentially leaving up to 301 archaeological sites (and any undiscovered sites present) exposed during critically dry conditions.

For preservation risk, the Enhanced Coordination Alternative is the most robust for Lake Powell, with 47 percent of the modeled futures over the full modeling period meeting the 2.72 threshold, followed by the Maximum Operational Flexibility Alternative with 28 percent of futures. This relational pattern is consistent if the full modeling period is broken out into shorter ranges, including the first decadal period (2027–2039) where the Enhanced Coordination Alternative also performs the best at 30 percent of futures, followed again by the Maximum Operational Flexibility Alternative at 25 percent of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust for Lake Mead, meeting the 2.24 risk threshold in 24 percent of the modeled futures over the full modeling period, followed by the Maximum Operational Flexibility Alternative with 19 percent of futures. When examining the first decadal period (2027–2039) at Lake Mead, the percentage of futures meeting the preferred minimum of performance drops drastically. This is because the anticipated water levels for Lake Mead in 2027 are expected to be low and for this reason, robustness modeling shows a substantial drop in performance. For this first 10-year period, the Supply Driven Alternative (both LB Priority and LB Pro Rata) continues to perform the best, but only at 5 percent of futures, followed by the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative, and the Representative Preferred Alternative, all three of which meet the preferred level of performance in only 3 percent of futures.

Overall, for Lake Powell, the Enhanced Coordination and the Maximum Operational Flexibility Alternatives perform better in drier conditions and have the greatest potential to expose fewer archaeological sites and protect more through inundation. For the preservation risk model results, this is true for the full modeling period or for the first decadal period (2027–2039); however, the percentage at which the threshold of 2.72 for Lake Powell is met declines drastically approaching critically dry conditions for the first 10-year period.

For Lake Mead overall, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives perform better in drier conditions. This can be seen in the results from the preservation risk model for the full modeling period; however, for the first 10-year period (2027–2039) the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is followed closely by the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative, and the Representative Preferred Alternative under critically dry conditions. Overall, preservation risk for the Representative Preferred Alternative falls in the middle for both lakes compared to the other modeled scenarios as conditions become drier. The No Action and Basic Coordination Alternatives have the greatest potential to expose the most archaeological sites (thereby protecting the fewest sites) at both lakes.

River Flows

For the reaches between Glen Canyon Dam and Lake Mead and Hoover Dam to Lake Mohave, in the Wet and Average Flow Categories, all modeled scenarios generally fall within the ranges of past release volumes. However, in the Critically Dry Flow Category, the median WY release volumes all fall below 7.0 maf for the reach below Glen Canyon Dam, with the Enhanced Coordination Alternative falling to 5.1 maf. The Representative Preferred Alternative has the narrowest interquartile range under critically dry hydrological conditions, with the upper limit at around 6.6 maf, which is still below the bottom of the range of past flow volumes at 7.0 maf. Below Hoover Dam, median CY release volumes all fall at or below 8.0 maf, with the Representative Preferred Alternative at around 7.2 maf. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have the poorest performance, falling as low as 6.4 maf for CY releases. Therefore, under the Critically Dry Flow Category, there is greater potential for sites to be impacted by fluctuating water levels; however, any impacts, if they occur, would be to those sites closest to the riverbanks.

Below Davis Dam, little to no impacts, regardless of flow category, are expected. This is because the dams below Lake Mohave are operated under guidelines that maintain lake elevations or target water deliveries. Also, they have several stretches of channelized banks.

Issue 2: How will changes in dam operations affect sediment availability for aeolian transport in the Grand Canyon?

Based on the aeolian transport model for the full modeling period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would have the best outcome for increasing the availability of sand for wind transport to protect archaeological sites. Both alternatives have a similar percentage of futures meeting the minimum preferred performance in at least 1 out of every 3 years at 19 and 18 percent, respectively. Although this is a small percentage, the two alternatives perform

better than the No Action, Basic Coordination, the Representative Preferred, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives as well as the CCS Comparative Baseline, which all have values at 9 percent or lower. This changes, however, when examining the first decadal period (2027–2039) where the No Action Alternative performs the best, meeting the preferred minimum performance in 38 percent of futures, followed by the Enhanced Coordination Alternative at 35 percent and the Maximum Operational Flexibility Alternative at 30 percent in 1 out of every 3 years. The Basic Coordination Alternative, CCS Comparative Baseline, and Representative Preferred Alternative perform similarly at 19 percent, 18 percent, and 17 percent, respectively, but all still notably perform more poorly than the No Action and Enhanced Coordination Alternatives. The Supply Driven Alternative (both the LB Priority and LB Pro Rata approaches) performs the worst, meeting the preferred minimum performance in only 9 percent of futures.

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Technical Appendix 12

Paleontological Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
BLM	Bureau of Land Management
CCS	Continued Current Strategies
cfs	cubic feet per second
Department	United States Department of the Interior
DMDU	Decision Making under Deep Uncertainty
GCMRC	Grand Canyon Monitoring and Research Center
HFE	high-flow experiment
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
NPS	National Park Service
NRA	National Recreation Area
PFYC	Potential Fossil Yield Classification
PRPA	Paleontological Resources Preservation Act
Reclamation	Bureau of Reclamation
SIB	Southerly International Boundary
U.S.	United States
USGS	United States Geological Survey

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TA 12. Paleontological Resources

TA 12.1 Affected Environment

Paleontological resources include any fossilized remains, traces, or imprints of organisms preserved in rock. The Paleontological Resources Preservation Act of 2009 (PRPA; 16 United States [U.S.] Code 470aaa–470aaa-11) and its implementation rule (43 Code of Federal Regulations 49) require that U.S. Department of the Interior (Department) agencies preserve, manage, and protect paleontological resources on lands administered by the Bureau of Reclamation (Reclamation), the National Park Service (NPS), the Bureau of Land Management (BLM), and the U.S. Fish and Wildlife Service. The PRPA ensures these federally owned resources are available for current and future generations to enjoy and study as part of America's national heritage.

The Colorado River Basin, a region renowned for its rich biodiversity and invaluable paleontological resources, faces a range of significant challenges stemming from fluctuating water levels, climate trends, and increasing human demands. As one of the most heavily managed rivers in the U.S., its waters are primarily allocated for agricultural, urban, and hydropower needs. However, this management, while crucial for sustaining these sectors, inadvertently impacts the delicate ecosystems that rely on the river's flow. Beyond the biological consequences, the fluctuating water levels also affect the paleontological sites embedded within the riverbanks and surrounding landscapes. Fossils, trackways, and other paleontological remains, often hidden beneath layers of sediment, are increasingly exposed as water levels fluctuate, leaving them vulnerable to erosion, weathering, and human disturbances. Fossils are nonrenewable resources and once degraded or destroyed can result in the permanent loss of important scientific information about life and environments in the earth's past. Proper management actions can identify how to reduce impacts on paleontological resources, leading to their preservation and enhancing our knowledge of earth and life through time.

The NPS is primarily responsible for conservation of natural and cultural resources and the visitor experience, including recreation, at both Lake Mead and Lake Powell. Reclamation manages water operations. Both agencies comply with the PRPA.

The Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (2007 Final EIS; Reclamation 2007) and the 2024 Glen Canyon Dam Long-Term Experimental Management Plan (LTEMP) Final Supplemental Environmental Impact Statement (Reclamation 2024a) do not address paleontological resources as a separate resource concern; the Near-term Colorado River Operations Final Supplemental Environmental Impact Statement does (Reclamation 2024b). In the 2007 and 2024 analyses, many potential impact issues related to reservoir levels and changes in river flows are analogous to those for cultural resources, such as paleontological resources.

TA 12.1.1 Study Area

The study area for paleontological resources stretches from the northern extent of Lake Powell to the Southerly International Boundary (SIB) in California. It covers approximately 1 million acres across Utah, Arizona, Nevada, and California. The study area encompasses the Colorado River channel from bank to bank, extending from the canyon rim to canyon rim in areas from Glen Canyon Dam to Lake Mead through the Grand Canyon. A 0.5-mile buffer is applied to the full-pool volume of Lake Powell and Lake Mead. The same buffer is applied to the lower Colorado River corridor from Hoover Dam to the SIB. This includes the known and unknown resources in Lake Powell and Lake Mead. It is important to note that the resources within fluctuating water levels are vulnerable to wave action; those above are at risk from visitation impacts.

This region of the southwestern U.S. contains a rich paleontological record, with fossils and traces of marine and terrestrial life preserved in the sedimentary strata, dating back over 1.2 billion years (Santucci and Tweet 2021). However, much of these resources have been submerged by the creation of the reservoirs at Lake Powell and Lake Mead, with minimal data available on the deepwater zones, which are less vulnerable to disturbance. In contrast, the operational zones and areas above fluctuating water levels, which have been partially inventoried, are at greater risk from erosion, wave action, and human activity. Erosion, accelerated by land and water management along the Colorado River, exposes fossils more quickly, providing opportunities for discovery but also increasing the risk of loss. As water levels fluctuate, previously submerged fossils are exposed to environmental threats like wind, sun, and temperature fluctuations, causing weathering and degradation.

The PRPA requires federal protection, but the ongoing exposure of these resources highlights the need for more effective preservation efforts. The PRPA also requires Department agencies to develop plans to inventory and monitor using scientific principles and expertise. These plans should emphasize interagency coordination and collaborative efforts, when possible.

Paleontological Resources Assessment Criteria

In recognizing that paleontological resources are considered to include not only fossil remains and traces but also the fossil-collecting localities and the geologic units containing those fossils and localities, the BLM developed a procedure for evaluating the paleontological resource potential of individual geologic units. This procedure uses the Potential Fossil Yield Classification (PFYC) system to assign ranks to geologic units based on the relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils and the sensitivity of these fossils to adverse impacts (BLM 2007, 2016). Under the PFYC system, geologic units with a higher potential are assigned a higher classification number. The PFYC system, as defined by the BLM, is used by other Department agencies (BLM-IM-2016-124) and is outlined as follows:

PFYC Class 5—Very High
This class includes highly fossiliferous geologic units that consistently and predictably produce significant paleontological resources. Units assigned to Class 5 have some or all of the following characteristics:

- Significant paleontological resources have been documented and occur consistently.
- Paleontological resources are highly susceptible to adverse impacts from surface-disturbing activities.
- The unit is frequently the focus of illegal collecting activities.

PFYC Class 4—High
This class includes geologic units that are known to contain a high occurrence of paleontological resources. Units assigned to Class 4 typically have the following characteristics:

- Significant paleontological resources have been documented but may vary in occurrence and predictability.
- Surface-disturbing activities may adversely affect paleontological resources.
- Rare or uncommon fossils, including nonvertebrate (such as soft body preservation) or unusual plant fossils, may be present.
- Illegal collecting activities may impact some areas.

PFYC Class 3—Moderate
This class includes sedimentary geologic units where fossil content varies in significance, abundance, and predictable occurrence. Units assigned to Class 3 have some of the following characteristics:

- They are marine in origin with sporadic known occurrences of paleontological resources.
- Paleontological resources may occur intermittently, but abundance is known to be low.
- Units may contain significant paleontological resources, but these occurrences are widely scattered.
- The potential for an authorized land use to impact a significant paleontological resource is known to be low to moderate.

PFYC Class 2—Low
This class includes geologic units that are not likely to contain paleontological resources. Units assigned to Class 2 typically have one or more of the following characteristics:

- Field surveys have verified that significant paleontological resources are not present or are very rare.
- Units are generally younger than 10,000 years before present.
- There are recent aeolian deposits.
- Sediments exhibit significant physical and chemical changes (that is, diagenetic alteration) that make fossil preservation unlikely.

PFYC Class 1—Very Low
This class includes geologic units that are not likely to contain recognizable paleontological resources. Units assigned to Class 1 typically have one or more of the following characteristics.

- The geologic units are igneous or metamorphic, excluding air-fall and reworked volcanic ash units.
- The geologic units are Precambrian (for example, Proterozoic) in age.

PFYC Class U—Unknown
This class includes geologic units that cannot receive an informed PFYC assignment. Characteristics of Class U may include the following:

- The geologic units may exhibit features or preservation conditions that suggest significant paleontological resources could be present, but little information about the actual paleontological resources of the unit or area is known.
- The geologic units represented on a map are based on lithologic character or basis of origin, but they have not been studied in detail.
- Scientific literature does not exist or does not reveal the nature of paleontological resources.
- Reports of paleontological resources are anecdotal or have not been verified.
- The area or geologic unit is poorly studied or understudied.
- BLM staff has not yet been able to assess the nature of the geologic unit.

PFYC Class W—Water
This class includes any surface area that is mapped as water. Most bodies of water do not normally contain paleontological resources. However, shorelines should be carefully considered for uncovered or transported paleontological resources. Reservoirs are a special concern because important paleontological resources are often exposed during low water intervals. In karst areas, sinkholes and cenotes may trap animals and contain paleontological resources. Dredging river systems may result in the disturbance of sediments that contain paleontological resources.

Deep Time and the Geologic Time Scale

Earth's history extends back more than 4.6 billion years and reflects a long and complex sequence of physical and biological events. To organize this vast span of time, geologists developed the geologic time scale, which serves as an international framework for describing the earth's past. The time scale divides geologic history into formally named intervals—such as eras, periods, and epochs—based on rock sequences that preserve evidence of past environments, geologic events, and life forms.

Similar to how a calendar divides a year into months, weeks, and days, the geologic time scale uses a hierarchy of time units that allows scientists to describe events at different levels of detail. The names of these intervals were often derived from geographic regions where representative rock formations were first studied.

When the time scale was first developed in the 18th and 19th centuries, it was based on relative dating, recognizing that in an undisturbed sequence of rock layers, the lower layers are older than

those above. With the discovery of radioactivity in the late 19th century, scientists gained the ability to determine absolute ages of rocks by measuring the decay of radioactive isotopes. This advancement made it possible to assign numerical ages to geologic time intervals and better understand the timing of major geologic and biological events.

Figure TA 12-1, below, depicts the geologic time scale put together by the NPS, and includes the geologic time divisions discussed in the text and included in the PFYC geodatabase. **Figure TA 12-2** is a more in-depth depiction of the time scale.

Table TA 12-1 summarizes the number of acres by PFYC value in the study area. **Map TA 12-1** through **Map TA 12-8** depict PFYC values in the study area. These PFYC maps were created by first compiling a composite geologic map of the study area and then assigning PFYC rankings to each geologic rock unit.

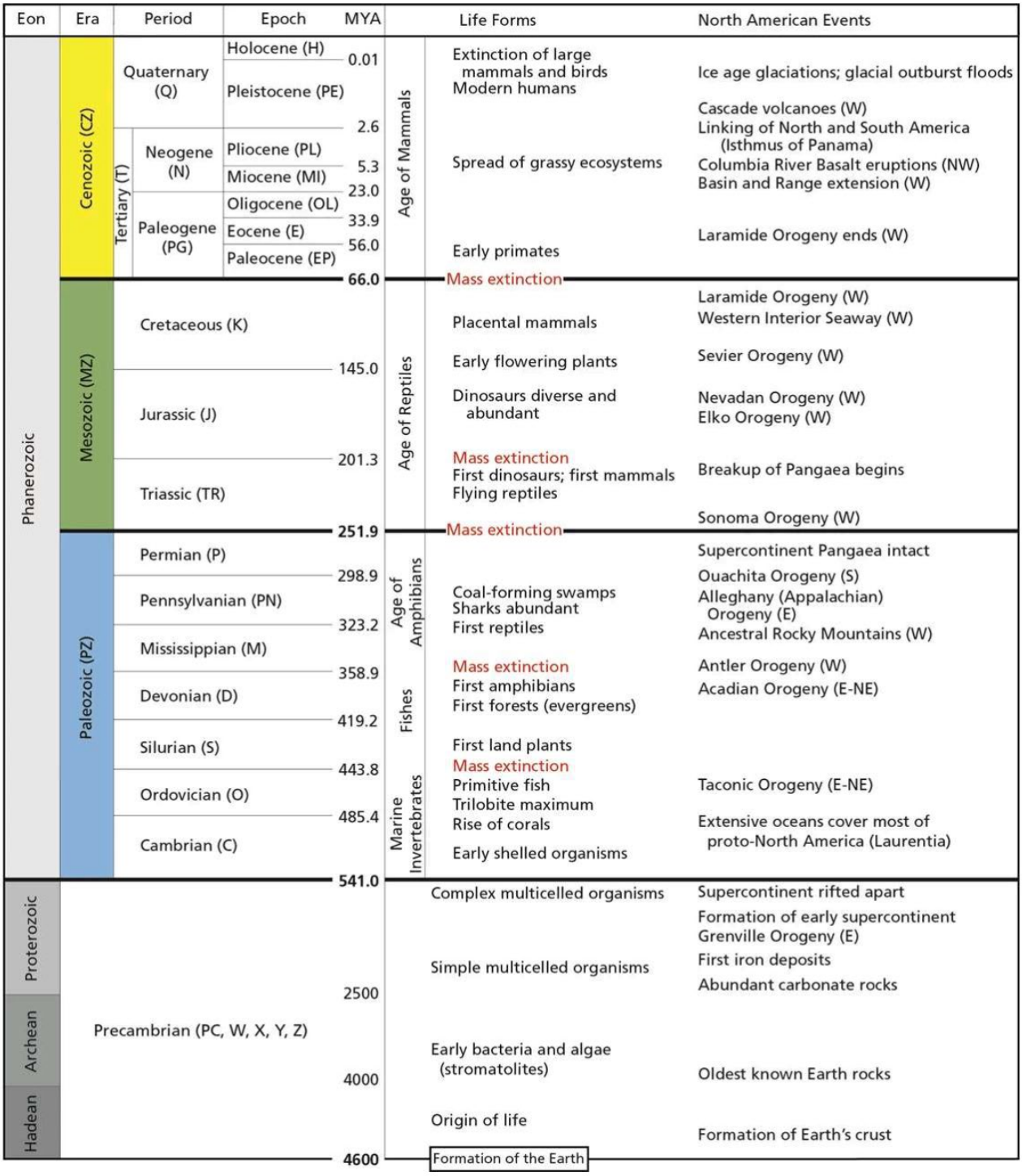
Table TA 12-1
Acres of PFYC within the Study Area

PFYC	Total Acres
1	70,500
2	154,600
3	103,600
4	179,300
5	24,200
U	113,700
W	373,100
Total acres	**1,019,000**

Source: BLM GIS 2025
Note: PFYC data do not cover the entire study area, especially in the waterbodies and portions of the Colorado River.

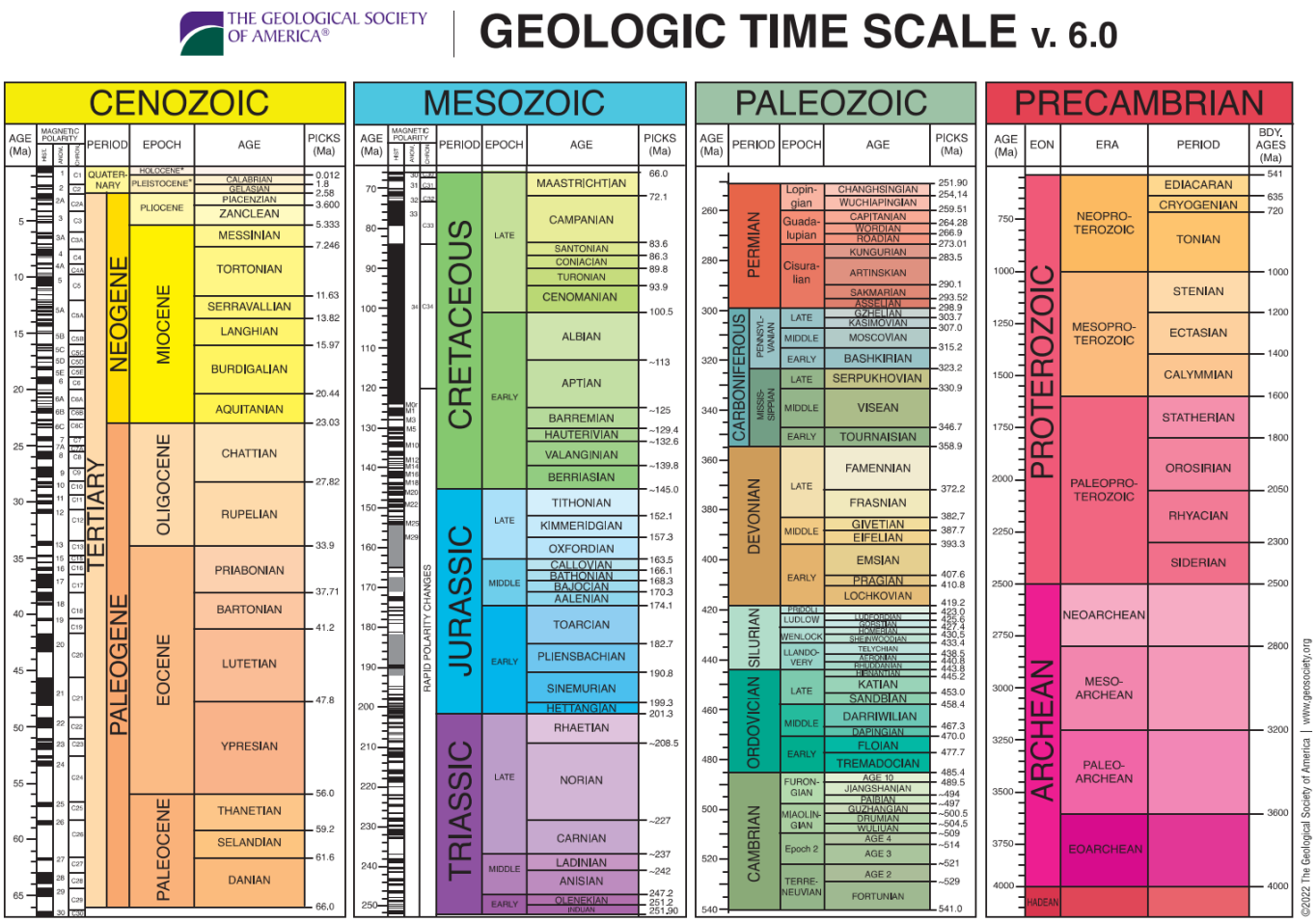
Formation-by-formation summaries of resource type, distribution, and PFYC system classes for all geologic units in the study area are in **Table TA 12-2**.

Figure TA 12-1
Simplified Geologic Time Scale



Source: NPS 2018

Figure TA 12-2
Geologic Time Scale



*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages: Calabrian from 1.8 to 0.774 Ma, Chibanian from 0.774 to 0.129 Ma, and Late from 0.129 to 0.0117 Ma. The Holocene is divided into three ages: Greenlandian from 0.0117 to 0.0082 Ma, Northgrippian from 0.0082 to 0.0042 Ma, and Meghalayan from 0.0042 to present. The geologic community broadly recognizes the Anthropocene as a proposed new time interval of Earth history, partly coincident with the Holocene. Currently, the Anthropocene has an informal designation, with a proposed age span extending from the present to a beginning point between ca. 15,000 yr B.P. and as recent as 1960 CE.

The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries usually follow the Gradstein et al. (2012), Cohen et al. (2012), and Cohen et al. (2013, updated) compilations. Numerical age estimates and picks of boundaries usually follow the Cohen et al. (2013, updated) compilation. The numbered epochs and ages of the Cambrian are provisional. A "~" before a numerical age estimate typically indicates an associated error of ± 0.4 to more than 1.6 Ma.

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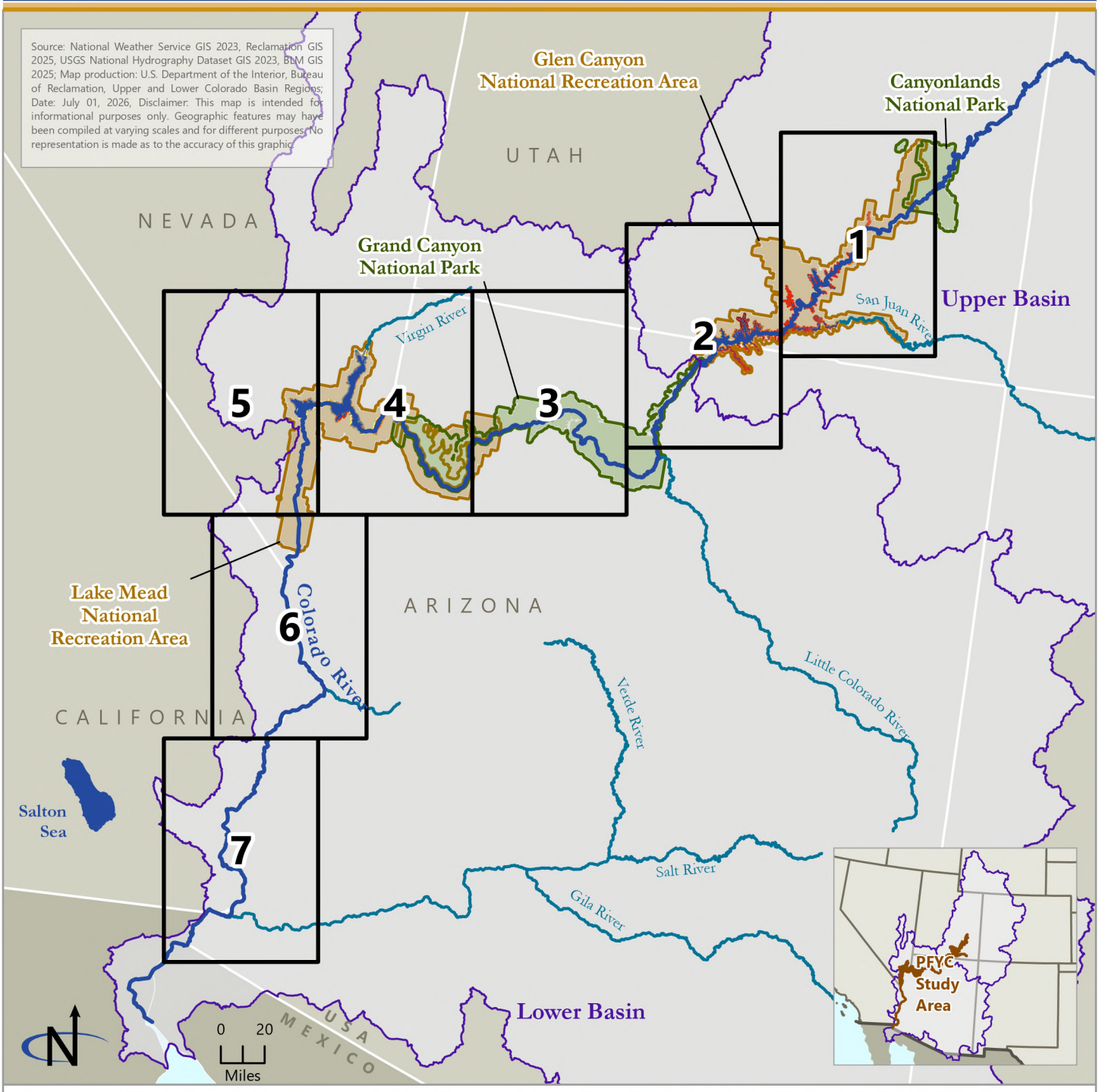
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Source: GSA 2022

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Map TA 12-1
Potential Fossil Yield Classification—Overview

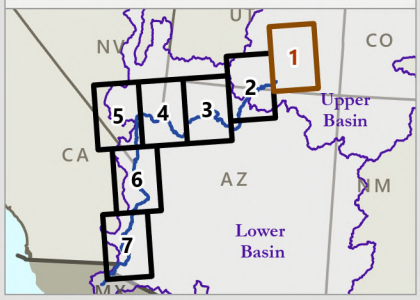


- Class 5—Very high
- Class 4—High
- Class 3—Moderate
- Class 2—Low
- Class 1—Very low
- Class U—Unknown
- Class W—Water
- Map extent
- Colorado River
- Major Colorado River tributary
- National park
- National recreation area
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

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Map TA 12-2
Potential Fossil Yield Classification—Extent 1

Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023, BLM GIS 2025; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: July 01, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.



Canyonlands National Park

Upper Basin

Glen Canyon National Recreation Area

San Juan River

UTAH

ARIZONA

Class 5—Very high
Class 4—High
Class 3—Moderate
Class 2—Low
Class U—Unknown
Class W—Water

Colorado River
Major Colorado River tributary
National park
National recreation area
Colorado River Basin, Upper and Lower Basins

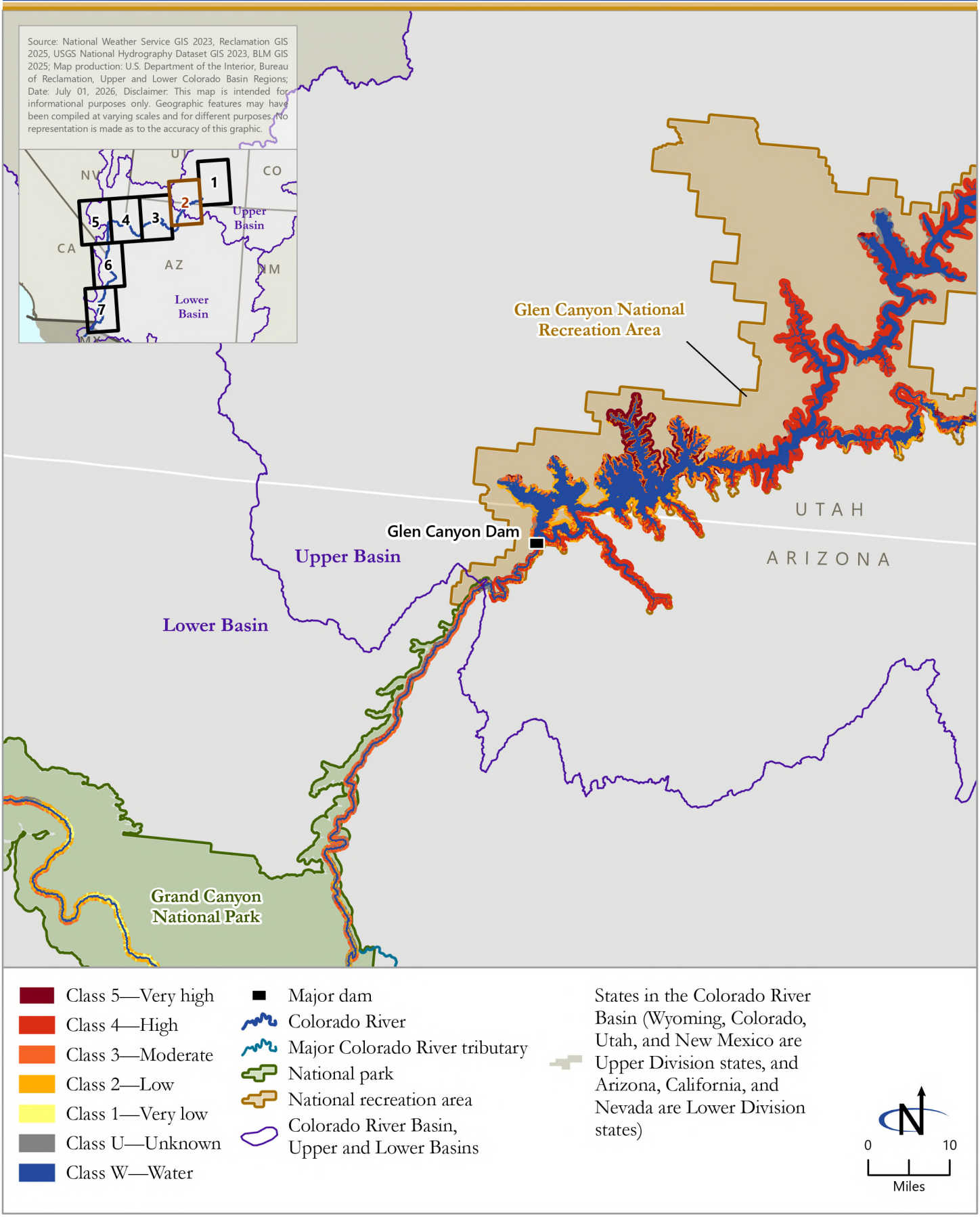
States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

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Miles

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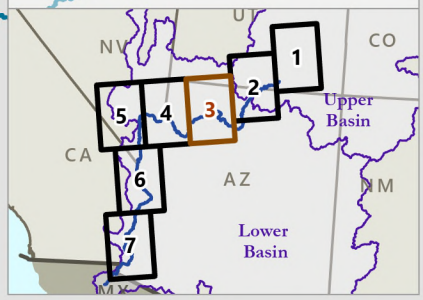
Map TA 12-3
Potential Fossil Yield Classification—Extent 2



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Map TA 12-4
Potential Fossil Yield Classification—Extent 3

Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023, BLM GIS 2025; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: July 01, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.



UTAH

Upper Basin

Lower Basin

ARIZONA

Grand Canyon National Park

Lake Mead National Recreation Area

Class 4—High
Class 3—Moderate
Class 2—Low
Class 1—Very low
Class U—Unknown
Class W—Water

Colorado River
Major Colorado River tributary
National park
National recreation area
Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

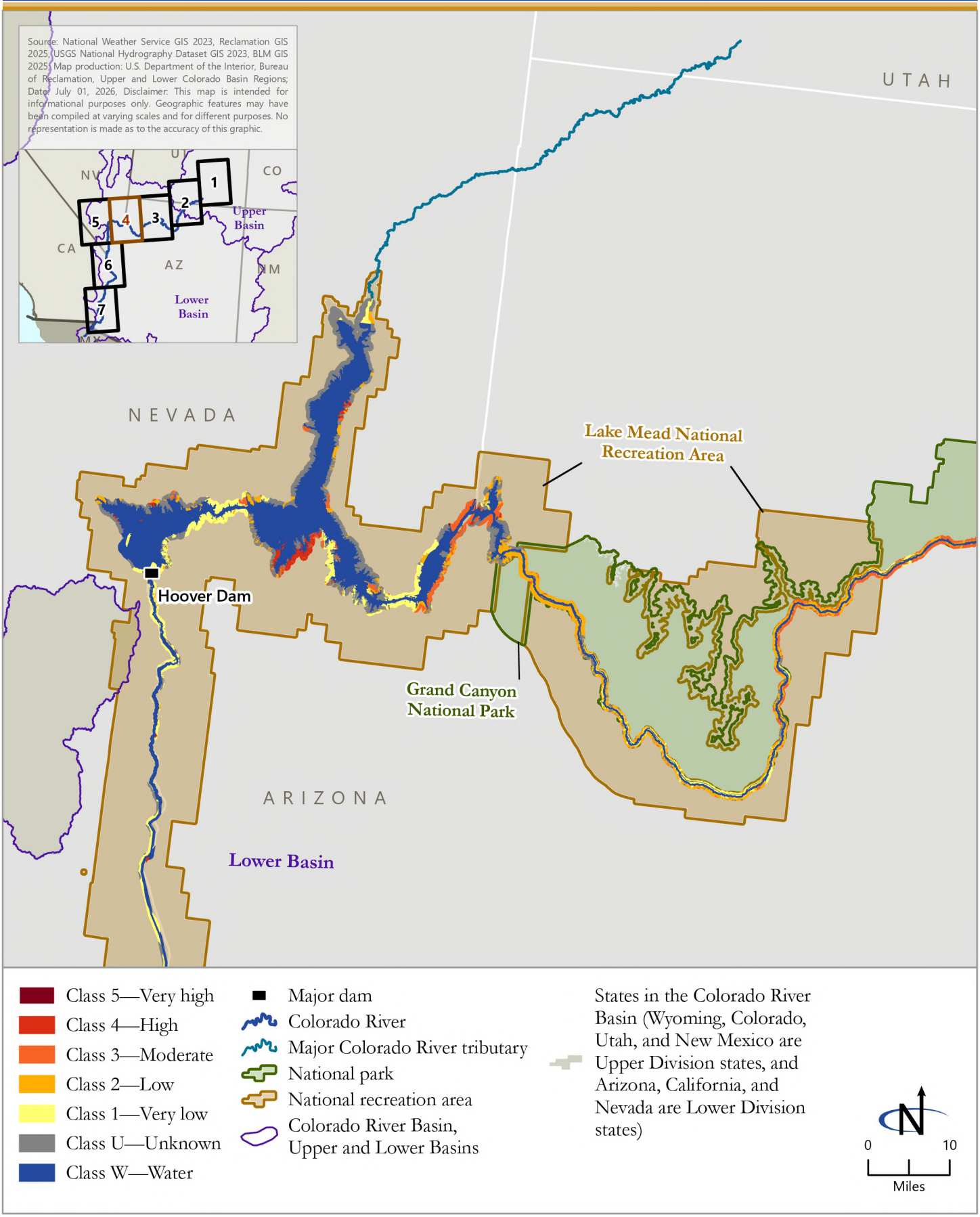
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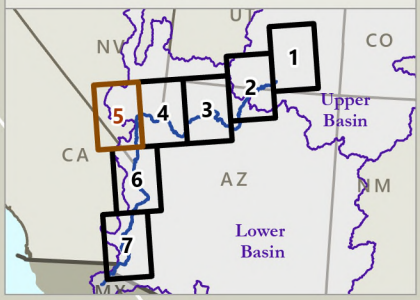
Map TA 12-5
Potential Fossil Yield Classification—Extent 4



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Map TA 12-6
Potential Fossil Yield Classification—Extent 5

Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023, BLM GIS 2025; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: July 01, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.



Lake Mead National Recreation Area

NEVADA

Hoover Dam

CALIFORNIA

ARIZONA

Lower Basin

- Class 4—High
- Class 3—Moderate
- Class 2—Low
- Class 1—Very low
- Class U—Unknown
- Class W—Water
- Major dam
- Colorado River
- Major Colorado River tributary
- National recreation area
- Colorado River Basin, Upper and Lower Basins
- States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

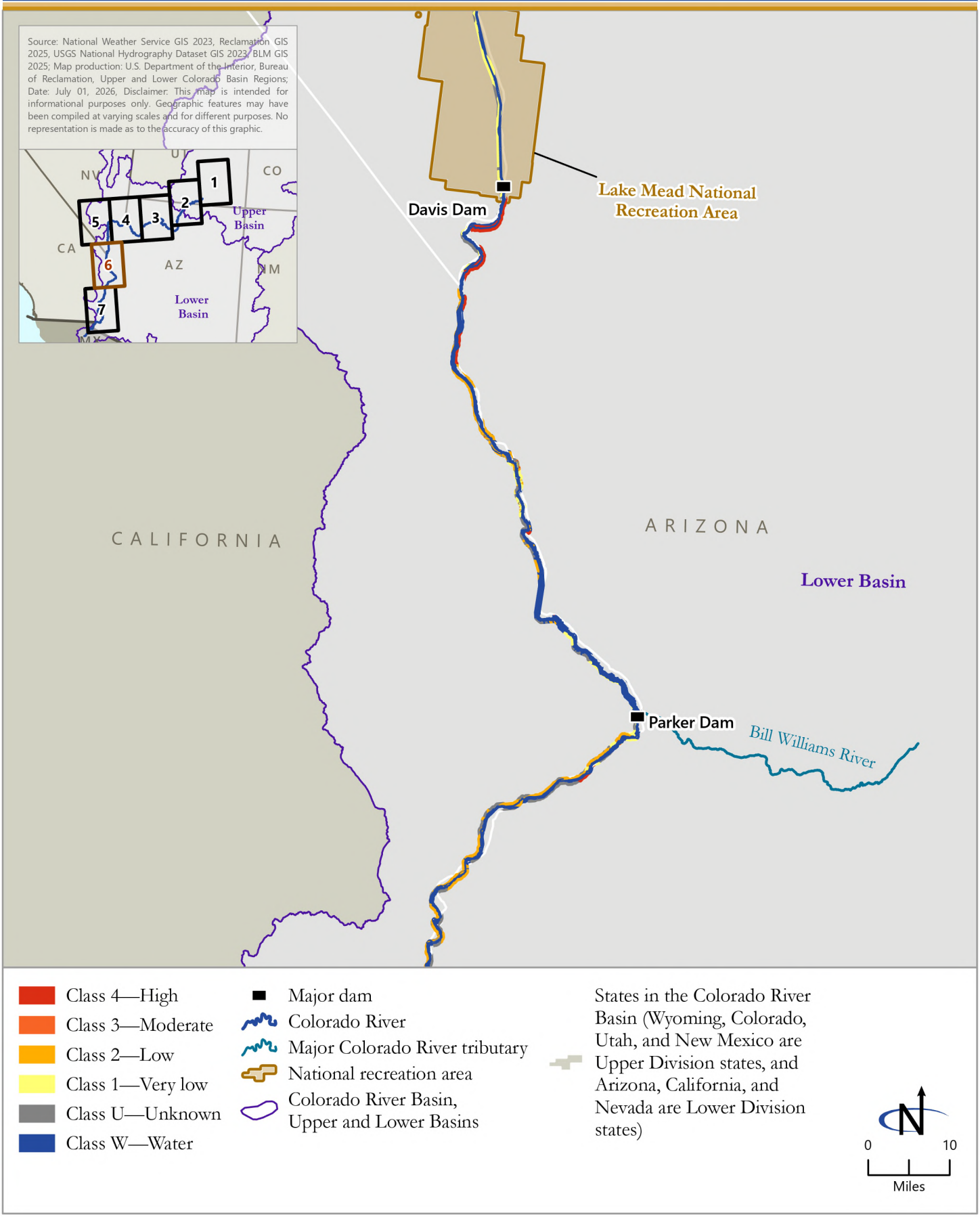
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RECLAMATION

Map TA 12-7
Potential Fossil Yield Classification—Extent 6



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Map TA 12-8
Potential Fossil Yield Classification—Extent 7

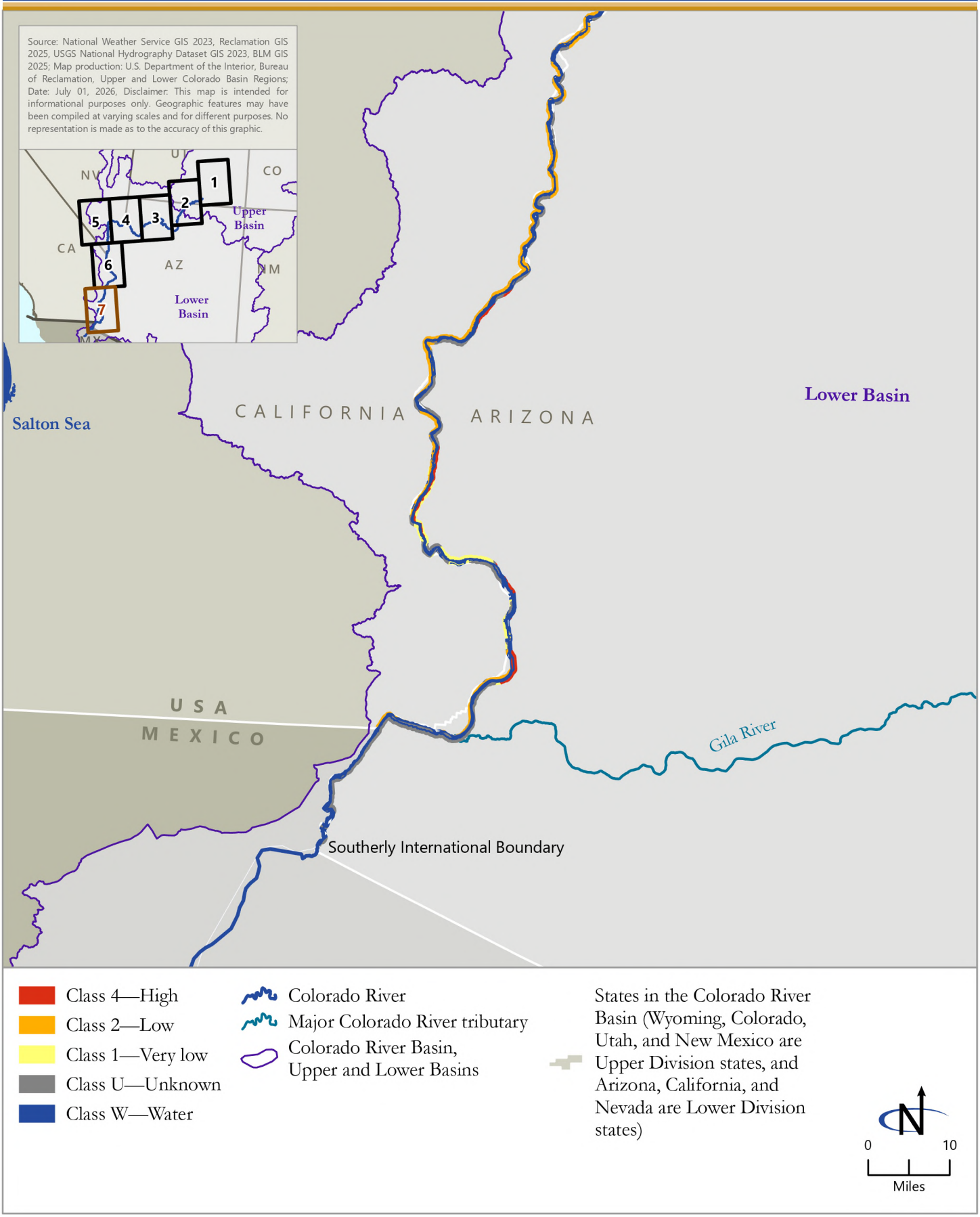


Table TA 12-2
Geologic Units of High and Very High PFYC Value within the Study Area

PFYC Value	Geologic Unit	Geologic Age
Glen Canyon National Recreation Area (NRA), including Lake Powell and the Colorado River with a 0.5-mile buffer		
4	Glen Canyon Group Glen Canyon Group (Navajo, Kayenta, Wingate, and Moenave Formations) and Nugget Sandstone Hoskinnini Sandstone Member Judd Hollow Tongue and Page Sandstone Tongues Kayenta Formation Kayenta Formation, undivided Lower red member, Virgin Limestone Member, and middle red member, undivided of the Moenkopi Formation Moenave Formation and Wingate Sandstone, undivided Moenkopi Formation Moenkopi, Dinwoody, Woodside, Thaynes, and other formations Moss Back Member of Chinle Formation Navajo Sandstone Navajo Sandstone of the Glen Canyon Group Page Sandstone Springdale Sandstone Member Summerville, Entrada, Carmel, Arapien, Twin Creek, and other formations Tropic Shale Upper member of Moenkopi Formation	Mesozoic
	Lower Cutler beds	Paleozoic
5	Church Rock Member of Chinle Formation Dakota Formation Monitor Butte Member of Chinle Formation Morrison Formation Morrison Formation Owl Rock and Petrified Forest Members of Chinle Formation Owl Rock Member of the Chinle Formation Petrified Forest Member of the Chinle Formation Shinarump Member of the Chinle Formation	Mesozoic
Glen Canyon NRA southwest boundary (approximately Marble Canyon) to Lake Mead NRA eastern boundary (majority is in the Grand Canyon National Park)		
4	Lower red member, Virgin Limestone Member, and middle red member, undivided of the Moenkopi Formation	Mesozoic
	Hermit Formation	Paleozoic

PFYC Value	Geologic Unit	Geologic Age
Lake Mead NRA, including Lake Mead and Colorado River with a 0.5-mile buffer		
4	Muddy Creek Formation, Fine-grained facies Muddy Creek Formation, Gypsum facies Muddy Creek Formation, Limestone facies Muddy Creek Formation, Tuff bed Sedimentary deposits	Cenozoic
	Hermit Formation Hermit Formation and Esplanade Sandstone, undivided	Paleozoic
Lower Colorado River from Davis Dam to SIB		
4	Chemehuevi Formation Chemehuevi Formation, gypsiferous mud Sedimentary deposits	Cenozoic
5	Tapeats Sandstone and Bright Angle Shale	Paleozoic

Source: BLM GIS 2025

Lake Powell and Glen Canyon Dam

The Glen Canyon NRA, encompassing portions of southern Utah and northern Arizona, contains one of the most extensive and complete sedimentary records on the Colorado Plateau. The stratigraphic sequence within Glen Canyon NRA exceeds 10,000 feet in cumulative thickness and represents approximately 300 million years of the earth's geologic history (Anderson et al. 2010). These strata chronicle a dynamic history that includes the assembly and breakup of the supercontinent Pangea, repeated transgressions and regressions of shallow inland seas, the development of vast eolian dune systems, and the incision of the modern Colorado River (Graham 2020). The resulting depositional environments—marine, fluvial, lacustrine, and eolian—record the complex interplay of tectonics, sedimentation, and biological evolution that shaped the region through Paleozoic, Mesozoic, and Cenozoic time.

Lake Powell, a reservoir formed by the impoundment of the Colorado River behind Glen Canyon Dam, occupies the central portion of Glen Canyon NRA. The reservoir extends approximately 186 miles and includes nearly 1,960 miles of shoreline with 96 major side canyons. Fluctuations in the lake level due to dam operations and hydrologic variation periodically expose new rock surfaces, revealing fossil-bearing strata that had been previously submerged (Milner et al. 2024). These exposures, along with naturally eroding canyon walls, make the area an important locality for the discovery and documentation of paleontological resources.

Glen Canyon NRA preserves fossil assemblages spanning the Paleozoic, Mesozoic, and Cenozoic Eras, offering insights into changing environments and biotic communities through time. Paleozoic formations, including the Kaibab Limestone and Toroweap Formation, contain abundant marine fossils, such as brachiopods, crinoids, and corals, which reflect deposition in warm, shallow marine environments during the Permian Period. Overlying Triassic units, such as the Moenkopi and Chinle Formations, record a transition to continental fluvial environments. These strata preserve vertebrate trackways, petrified wood, and early dinosaur remains, documenting faunal diversification following the Permian-Triassic extinction event. The Chinle Formation, in particular, is world-renowned for its

early dinosaur tracksites and vertebrate assemblages, which record one of the earliest radiations of dinosaurs in North America (Graham 2016). Although there are limited areas mapped for the Coconino Sandstone, Toroweap Formation, Hermit Shale, Kaibab Formation, and Dinosaur Canyon Member of the Moenave Formation in the southern areas of Glen Canyon NRA—all known to be fossiliferous at localities outside Glen Canyon NRA—no fossils have been reported yet from any of these units in the recreation area (Milner et al. 2024).

The overlying Jurassic formations of the Glen Canyon Group—including the Wingate, Kayenta, and Navajo Sandstone—capture the transition from fluvial to eolian depositional systems. The Wingate and Kayenta Formations preserve small vertebrate fossils and trackways, while the Navajo Sandstone records a vast ancient dune field representing one of the largest preserved erg systems in the geologic record. These formations are particularly rich in vertebrate trace fossils, including extensive trackways of dinosaurs, reptiles, and amphibians (Milner et al. 2024). Many of these tracksites occur along the modern shoreline of Lake Powell, where fluctuating water levels periodically uncover new fossil surfaces.

In 2023, receding lake levels revealed a previously submerged fossil locality within the Navajo Sandstone, where paleontologists discovered a tritylodontid mammaliaform bonebed dating to approximately 180 million years ago. This discovery represents one of the most complete early mammal-relative assemblages yet documented in the Navajo Sandstone and provides valuable insight into vertebrate evolution during the Early Jurassic (NPS 2023).

Cretaceous formations, including the Naturita Formation and Tropic Shale, preserve a record of the Western Interior Seaway and contain marine invertebrates, plant fossils, and marine reptiles, illustrating the return of widespread marine conditions during the mid-Cretaceous (Titus et al. 2016). Alcoves, including the best-known Quaternary site (Bechan Cave), are important fossil sites associated with fossil dung in Glen Canyon NRA. Fossil pollen and plant macrofossils preserved in packrat middens and dung deposits further document ecological and climatic changes during the Late Quaternary (Graham 2016; Mead et al. 2020).

Glen Canyon NRA staff is completing a paleontological resources inventory survey; because of the size of the recreation area, the survey is being done in phases, with the latest phase completed in 2024. The three inventory reports provide the baseline data for the breadth of paleontological resources found from Glen Canyon NRA. Despite these efforts, natural processes, such as erosion, mass wasting, and fluctuating water levels, continue to expose and degrade fossil-bearing strata. Additionally, anthropogenic influences, including reservoir sedimentation, vandalism, and unauthorized fossil collection, pose ongoing threats to resource preservation (Graham 2016; Santucci et al. 2009). In some areas, sediment accumulation resulting from dam operations may enhance fossil preservation by burial, while in others, it obscures or prevents discovery. Consequently, Glen Canyon NRA represents a dynamic and scientifically valuable setting where both natural and human processes continually shape the exposure, preservation, and accessibility of paleontological resources.

Grand Canyon National Park

The Colorado River corridor of Grand Canyon National Park contains paleontological resources of exceptional scientific significance, spanning nearly 1.2 billion years of the earth's history. The river corridor is renowned for its dramatic display of geomorphic effects created by fluvial incision and its unique dry preservation of fossils from the Ice Age (Mead et al. 2020). The river channel serves as the physical axis along which the park's oldest and youngest fossil-bearing strata are exposed. The river channel is organized into two principal paleontological occurrences documented in the Grand Canyon National Park Centennial Paleontological Resource Inventory (Santucci and Tweet 2021): ancient body and trace fossils preserved within the canyon's deep bedrock formations, and Pleistocene and Holocene fossils recovered from dry caves and sediment deposits along the corridor walls.

The oldest fossil-bearing rocks in the park are exposed along the river's edge in the eastern and central canyon. Precambrian sedimentary units of the Grand Canyon Supergroup (Bass Formation, Hakatai Shale, Dox Formation, Galeros Formation, and Kwagunt Formation) preserve stromatolites, acritarchs, and vase-shaped microfossils representing some of the earliest evidence of life documented in the National Park System, beginning approximately 1.25 billion years ago (Santucci and Tweet 2021). Above these, Cambrian units of the Tonto Group (Tapeats Sandstone, Bright Angel Shale, and Muav Limestone) are among the most fossil-rich formations accessible from the river corridor, preserving abundant invertebrate trace fossils, including burrows, trails, and feeding traces, as well as body fossils such as trilobites and brachiopods (Santucci and Tweet 2021). The Temple Butte Formation, exposed in isolated channel-cut pockets near the river in portions of the canyon, yields Devonian fish remains representing the earliest vertebrate fossils in the park (Santucci and Tweet 2021).

The river corridor is equally significant for its Pleistocene and Holocene fossil record. Dry caves and alcoves embedded in the corridor walls create the arid, sheltered conditions necessary to preserve organic material in exceptional detail (Mead et al. 2020). Among the most significant localities is Sandblast Cave, where excavations produced important data on the California condor, including a preserved nest, in addition to specimens of extinct mountain goat, bison, camel, and horse, along with the only reported mammoth remains from the Grand Canyon (Mead et al. 2020). Other fossil-bearing localities along the corridor include Stanton's Cave, Little Nankoweap, Skylight Cave, Hummingbird Cave, and Rampart and Vulture Caves in the western canyon, where thick deposits of Shasta ground sloth dung, hair, and skin were recovered (Mead et al. 2020). Packrat middens from these sites yield plant macrofossils, pollen, insects, and small vertebrate remains that document ecological and climatic shifts across the late Pleistocene and into the Holocene (Mead et al. 2020).

The objective of the Grand Canyon National Park Centennial Paleontological Resource Inventory was to identify the scope, significance, distribution, and management issues associated with fossils in the park (Santucci and Tweet 2021). The river corridor presents particular management challenges due to its difficult terrain and limited accessibility, and the inventory acknowledges that systematic survey of inner canyon fossil localities remains incomplete. Despite this, the Colorado River corridor constitutes one of the most scientifically valuable zones within Grand Canyon National Park.

Lake Mead and Hoover Dam

The Lake Mead NRA encompasses a geologically diverse landscape extending across portions of southeastern Nevada and northwestern Arizona. The stratigraphic record within Lake Mead NRA spans from the Paleozoic through Cenozoic Eras, representing more than 500 million years of the earth's history (BLM GIS 2025; Beard et al. 2007). These rocks preserve an array of marine, fluvial, and terrestrial depositional environments that document the evolution of the southwestern margin of the North American continent and provide an exceptional record of paleontological change through geologic time.

Fossils in Lake Mead NRA span the Paleozoic, Mesozoic, and Cenozoic Eras. Marine fossils such as trilobites and Cenozoic bivalves can be found along the Cottonwood Wash in Lake Mead, representing a crucial moment in the emergence of multicellular life on earth. As terrestrial landscapes dried up into the Jurassic Period 180 million years ago, present-day Lake Mead underwent a period of extensive erosion that resulted in a geological gap between the rock record of fossils until the later portion of the Cenozoic Era. Lake Mead has an impressive list of fossils documented from the Oligocene Epoch of the Cenozoic Era, particularly in the forms of mammals, amphibians, birds, and reptiles (NPS 2022).

The NPS completed a comprehensive paleontological resource inventory for Lake Mead NRA in 2018. While this inventory is confidential to the NPS, it established baseline data for fossil-bearing formations, recorded known localities, and assessed the relative potential for new discoveries. The report concluded that several formations have high fossil potential and merit continued monitoring and research. This inventory is the most recently completed report for the NRA.

Fluctuating lake levels have a direct influence on fossil exposure and preservation within Lake Mead NRA. Periods of low water levels at Lake Mead have exposed previously submerged geologic formations, resulting in increased accessibility to fossil-bearing strata along the shoreline. These exposures, while scientifically valuable, are also vulnerable to erosion and visitor impacts. As water levels fluctuate, cycles of inundation and exposure accelerate mechanical weathering and can lead to disarticulation or loss of fossil specimens. Conversely, sediment deposition in shallow nearshore zones may help preserve fossils by rapid reburial under fine-grained sediments.

Continued reductions in lake elevation are expected to expose additional outcrops of fossil-bearing formations, particularly along the upper reaches of the reservoir and tributary canyons. The NPS has identified these newly emergent areas as priorities for future surveying and monitoring. Overall, Lake Mead NRA contains a high diversity of paleontological resources, including the Miocene Horse Spring Formation, Muddy Creek Formation, and Pliocene and Pleistocene river gravels, that span marine, fluvial, and terrestrial systems, making it one of the most scientifically significant and geologically varied regions in the southwestern U.S.

Lower Colorado River Corridor

The lower Colorado River corridor follows the Colorado River from southern Nevada to the international border with the United Mexican States. Reclamation completed a paleontological resources inventory of the entire corridor in 2020 (Bonde and Slaughter 2020). The inventory report is confidential to Reclamation because it includes paleontological localities; however, the

information gained from this inventory expanded the knowledge of the paleontological record for the entire river corridor.

The sedimentary geologic record for the lower Colorado River corridor extends from the Middle Cambrian to the Pleistocene. While the geologic record is not fully continuous, units representative of most periods of geologic time are present in this area (Bonde and Slaughter 2020).

Current Conditions

Fluctuating water levels in both Lake Mead and Lake Powell pose significant threats to paleontological resources, including fossils and trackways preserved in sedimentary rocks. In reservoirs, cycles of inundation and exposure cause softer rocks like sandstone, which often contain delicate trackways, to become friable and more prone to erosion. As water levels drop, previously submerged fossils are exposed to environmental forces such as wind, sun, and temperature fluctuations, which accelerate the fossils' degradation. While sediment deposition can temporarily protect some sites, the exposure of fossil-rich layers as water levels recede increases the likelihood of weathering, fragmentation, and disturbance from human activity.

In addition to direct threats to fossils, fluctuating water levels disrupt the stability of sediment layers crucial for preserving these paleontological resources. The disturbance of these sediments destabilizes both the fossils themselves and the broader habitats they rely on. Sensitive plant species, animal burrows, and other ecological components can be damaged or destroyed as human activity increases in exposed areas. The exposure of fossil-rich sites also encourages further human impacts, such as increased recreational activities (hiking, off-highway vehicle use, and unauthorized fossil collection), which lead to soil compaction, vegetation trampling, and pollution from waste and chemicals, all of which undermine preservation efforts and hasten degradation.

Lands in the study area are subject to fluctuating water levels under current conditions. Water is a catalyst for erosion and a popular outlet for recreation. Possible water-related impacts that result in the threat or loss of paleontological resources in the study area include the following:

- Flooding events or controlled capture of reservoir levels lead to the elevation of water levels and consequent submersion of fossil-bearing rock layers.
- The controlled release of reservoir waters results in an increase in river velocity and downstream erosion rates, consequently removing fossil resources preserved in the geologic units that line the river corridors.
- Water systems are often associated with areas of high topographic relief formed from downcutting by a water source (that is, the steep canyon walls of the Grand Canyon carved by the Colorado River); these areas of high topographic relief are subject to higher rates of erosion and potential resources lost versus areas of lower topographic relief.
- Rivers and reservoirs are highly associated with recreation. The high density of people and popular use of public lands along the lower Colorado River may unintentionally invite theft, vandalism, or disturbance to fossil resources exposed along the margins of the waterways (Reclamation 2020).

Erosion is the primary agent that exposes paleontological resources on the surface to then await discovery and documentation. Lake Powell and Lake Mead are interconnected; adjustments of water releases at Lake Powell have a downstream effect on Lake Mead. The impacts on paleontological resources due to natural processes are the same at both reservoirs, but the intensity at which they occur and to what resources they occur vary. Paleontological resources in Glen Canyon NRA are largely more understood and considered to be highly scientifically important. As depicted in **Figure TA 12-8**, most of the area is ranked PFYC 4 (high) or PFYC 5 (very high). This is true at the mapped shorelines. In Lake Mead, the paleontological resources are less understood, and much of the shoreline is mapped PFYC U (unknown; **Figure TA 12-12**). Erosion concerns at Lake Powell are extremely high because erosion and other natural processes are impacting the geologic units with known high and very high paleontological value.

TA 12.2 Environmental Consequences

TA 12.2.1 Methodology

Changes in lake levels or river flows from the annual releases could directly and indirectly impact paleontological resources. Of greatest concern are effects on paleontological resources that degrade or that damage those resources before the resources can be preserved. Direct impacts may occur from processes such as wave action and wet-dry cycling. Direct impacts include any impact that is immediate in place and time; indirect impacts, such as those from increased visitation, are those that occur later in time.

Impacts on paleontological resources analyzed in this section only include those from Reclamation's management of the water in Lake Powell and Lake Mead. Two types of analyses are used to evaluate potential impacts on paleontological resources: preservation risk modeling developed by the U.S. Geological Survey (USGS) and NPS and aeolian transport-vegetation cover–high-flow experiment (HFE) joint modeling also developed by the USGS. Additionally, PFYC data were used to analyze areas of high fossiliferous potential within the study area.

Refer to **Section 3.2**, Analysis Methods, for additional information on Decision Making under Deep Uncertainty (DMDU) and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU conditional box plots, robustness heat maps, and vulnerability bar plots.

PFYC System

Paleontological localities were not used in this analysis because they are confidential and information is limited for an analysis at this scale. Instead, the BLM's PFYC system was used. As described above, the PFYC system is a tool used to predict impacts on fossil resources from planned actions. The system is straightforward: some rock units are more likely to contain scientifically interesting fossils than others. The assessment can be made by rock type and generalized from previously recorded fossil discoveries. The system is simple, ranked from 1 (very low potential) to 5 (very high potential), with a "U" category for unknown or understudied areas. The PFYC system is continuously updated by the BLM and other agencies, and it was used to map the entire study area.

Preservation Risk Modeling

The USGS, in cooperation with the NPS, developed a preservation risk model for paleontological resources at or below full-pool elevations at Lake Powell and Lake Mead (Caster et al. 2026). The preservation risk model is a spatial model that considers several landscape characteristics, locations of previously recorded paleontological resources, and the potential for water-related impacts such as wave action and erosion. The USGS mapped the shoreline areas and ranked the preservation risk from 1 (low) to 5 (high) based on low to high potential for resource preservation to be affected by water at a given reservoir elevation. The ranking incorporates two other models: (1) the PFYC system, which identifies where paleontological resources are more likely or less likely to be found, and (2) the Preservation Hazard Model, which identifies where site impacts related to lake fluctuations will likely occur.

The Preservation Hazard Model is based on the simplified physical factors influencing lake shore geomorphic change. Similar to coastal environments, wave action drives erosion, but reservoirs have the added risk of large, rapid, and sustained changes in water level that affect runoff base levels, soil deformation, and chemical weathering through submersion and exposure. These aspects were incorporated into the model using available USGS topography and bathymetric data and the known relationships between slope-wave interactions, base level adjustments, lake fetch lengths, and lake shoreline area change, as well as a given volume of reservoir storage loss. In this model, the highest rank (5) corelates to a higher potential for impacts, and the lowest rank (1) correlates to a lower risk from these factors. Human impacts, such as vandalism or unauthorized collection, are not included in this model.

When combining the PFYC and Preservation Hazard Models, a simple rule was used based on the assumptions that (1) regardless of hazard rank, areas likely to contain resources have the potential to be affected by lake management actions; (2) even where resource likelihood is low, hazards from water levels can impact a potentially significant resource; (3) areas with a very high likelihood of containing resources and a very high potential for impacts are at the highest risk of resource condition changes; and (4) areas with a very low likelihood of containing resources and a very low potential for impacts are at the lowest risk of resource condition changes.

The Preservation Hazard Model uses the same ranking system as the PFYC system. However, preservation risk ranks 1–5 are not equivalent to PFYC ranks 1–5.

Wind-Deposited Sediment

Research conducted by the USGS and NPS has demonstrated that wind-deposited (aeolian) sediment can help stabilize and preserve paleontological sites along the Colorado River over long periods of time (Santucci et al. 2009). Sediment is generally deposited via wind on nearby terraces at an average of a few millimeters a year; however, Glen Canyon Dam operations can inhibit the formation of sandbars from which the sediment is blown. Management of the Colorado River influences the supply of windblown river sand in two ways: (1) the reduction of river flows below current average baseflow levels causes sand in the river channel to be exposed subaerially, and given sufficient time, can dry out and become available for wind transport; and (2) when HFEs are successfully implemented to rebuild river sandbars, the sand in the subaerial portion of the sandbars

becomes available for wind transport. However, riparian vegetation can block the windblown transport of sand; when cover decreases, the potential for wind transport increases.

The analysis integrated three independent models: the aeolian sand availability model (hereafter referred to as the "Sand Area Model" by Kasprak et al. 2024), the Vegetation Habitat Suitability Model (Butterfield et al. 2018), and the Sandbar Volume Model (modified from Mueller and Grams 2021). The Sand Area Model was specifically developed to predict the supply of river-sourced, windblown sand as a function of river discharge and subaerial exposure time; however, the Sand Area Model used here does not incorporate changes in vegetation cover that occur as a function of river hydrology or geomorphic changes (deposition and erosion of sand) that would also affect sand area. Therefore, the Sand Area Model was coupled with outputs from the Marble Canyon Vegetation Habitat Suitability Model (Kelley et al. 2026). Scenarios were assessed in which modeled sand availability exceeded a defined threshold while vegetation suitability remained below a specific benchmark, indicating conditions favorable for aeolian transport.

To account for the dynamic influence of high-flow events, which can increase sandbar volume and enhance future sand supply, the Sandbar Volume Model output was then incorporated. In this analysis, a future is defined as a "preferred minimum performance" if one of the following logical criteria was met: (1) the Sand Area and Vegetation Habitat Suitability Models simultaneously exceeded and fell below their respective thresholds (suggesting favorable conditions for aeolian transport), or (2) the Sandbar Volume Model exceeded the threshold, indicating enhanced sand supply via fluvial-related deposition. Previous studies suggest that dam releases that allow these conditions to be met 1–3 years may slow the rate of degradation to enable time for mitigation and planning. Considering temporal variability of future acceptability, it is ideal if these conditions are met at least once every 3 years. Model thresholds were derived from recent historical baselines; the sand area and vegetation (Marble Canyon only) thresholds reflect the 50th percentile of model outputs from 2000 to 2023, while the sandbar volume threshold is set at 1.5 times the modeled initial condition beginning in 2027.

Impact Analysis Area

The impact analysis area for paleontological resources consists of the Colorado River corridor from the upper limits of Lake Powell, through the Grand Canyon and Lake Mead, and from Hoover Dam to the SIB.

Assumptions

- The analysis of physical impacts on paleontological resources resulting from changes in lake levels, river flows, and sediment changes is informed by the cultural resources analysis.
- Impacts on paleontological resources can be characterized based on projected lake elevations and river flows.
- The impact analysis area includes known, unrecorded, and predicted paleontological resources that may be submerged or exposed and those geologic units that are sensitive for the presence of scientifically important paleontological resources.
- Specific paleontological locations are not discussed in this analysis, but the level of information available is assumed to be sufficient for this broadscale analysis.

- The exposure of paleontological resources may lead to the discovery of scientifically important fossils; however, the process and practical means of recovering paleontological resources within the reservoirs or along the Colorado River channel are limited.
- Landforms with steeper slopes are more susceptible to wave action erosion compared with low-slope areas.

Impact Indicators

- End-of-year lake elevations that may expose paleontological resources to damage from wave action, wet-dry cycling, increased visitation, and unauthorized collection or vandalism
- Changes in river flows that may contribute to erosion and exposure of resources that may expose fossils and trackways to damage from erosion, wet-dry cycling, or increased visitation
- Increase or decrease in sandbar building and availability of windblown sediments to protect paleontological localities or exposed fossils

Summary of Impact Mechanisms

This section provides a high-level summary of the primary physical, environmental, and human-related mechanisms through which changes in reservoir elevations and river flows may affect paleontological resources within the impact analysis area. Paleontological resources in Lake Powell, in Lake Mead, and along the Colorado River corridor may be affected by processes associated with reservoir inundation and exposure, shoreline and channel erosion, sediment transport, weathering, and changes in human access. **Table TA 12-3** summarizes these mechanisms and describes the general ways in which each can affect the preservation, stability, and scientific integrity of fossils and trackways. The table is intended to orient the reader to the types of impacts evaluated in this chapter and does not distinguish differences in impact magnitude or severity among the alternatives, which are addressed in subsequent sections.

Table TA 12-3
Paleontological Resource Impact Mechanisms

Impact Mechanism	Description of Mechanism	Summary of Impacts on Paleontological Resources
Reservoir inundation and exposure	Fluctuations in Lake Powell and Lake Mead reservoir elevations alternately submerge and expose paleontological resources along shorelines and reservoir margins.	Repeated exposure increases vulnerability to physical and chemical degradation of fossils and trackways. Continuous inundation generally preserves paleontological resources more effectively than repeated cycles of exposure and inundation.
Wave action	Wind-driven wave energy acts on shoreline slopes and exposed reservoir margins, particularly where fetch length and slope increase wave power.	Mechanical erosion from wave action can undercut fossil-bearing strata, abrade exposed surfaces, and displace or destroy fossils and trackways, resulting in the loss of scientific context.

Impact Mechanism	Description of Mechanism	Summary of Impacts on Paleontological Resources
Wet-dry cycling	Reservoir drawdown and refill cause alternating periods of submersion and exposure.	These cycles accelerate the breakdown of fossil-bearing rock, particularly softer lithologies such as sandstone; this breakdown leads to cracking, spalling, loss of surface detail, and reduced integrity of fossils and track surfaces.
Chemical weathering	Prolonged contact with water followed by exposure to oxygen and atmospheric conditions breaks down or molecularly alters paleontological resources.	The weathering alters the mineral composition of enclosing rock, increasing friability after exposure and contributing to long-term degradation of fossils, even where physical erosion is limited.
Sunlight and ultraviolet exposure	Following reservoir drawdown, there is direct solar radiation on newly exposed fossil surfaces.	This exposure promotes surface weathering and thermal stress that can weaken fossil-bearing rock and accelerate degradation of exposed fossils and trackways.
Freeze–thaw processes	Seasonal temperature fluctuations allow water within fractures to freeze and expand, then thaw and contract.	These processes expand fractures and weaken rock matrices, increasing the likelihood of breakage, detachment, or loss of fossil material from outcrops.
Wind erosion	Wind acts directly on exposed sediments and fossil surfaces along reservoir margins and river terraces.	Wind erosion removes fine sediments that may otherwise protect fossils, abrades exposed surfaces, and increases rates of fossil degradation.
Fluvial erosion and deposition	Changes in river flows alter erosion and sediment deposition patterns along the Colorado River corridor.	Increased erosion can expose or damage fossils and trackways, while deposition and burial by fluvial sediments can temporarily protect paleontological resources from weathering and disturbance.
Aeolian sediment deposition	Windblown sand from exposed sandbars and river sediments accumulates on adjacent terraces and slopes.	Burial by aeolian sediments can stabilize and preserve paleontological resources over long periods by reducing exposure to erosion, weathering, and human disturbance.
Vegetation cover changes	Changes in river flows and sediment supply influence riparian vegetation extent, affecting windblown sediment transport.	Increased vegetation can limit aeolian sediment transport and reduce the natural burial of fossils, while reduced vegetation can enhance sediment deposition and protective burial.
Human access and visitation	Lower reservoir elevations expand exposed shorelines and increase accessibility by recreationists.	Trampling, inadvertent disturbance, vandalism, and unauthorized fossil collection may increase, resulting in loss of scientific context and irreversible damage to paleontological resources.

Impact Mechanism	Description of Mechanism	Summary of Impacts on Paleontological Resources
Unauthorized collection and vandalism	There can be intentional or opportunistic removal or defacement of exposed fossils.	Unauthorized collection permanently remove fossils from their geologic context, resulting in irreversible loss of scientific and educational value.

Note: This table provides a qualitative summary of impact mechanisms and does not distinguish differences in severity among the alternatives.

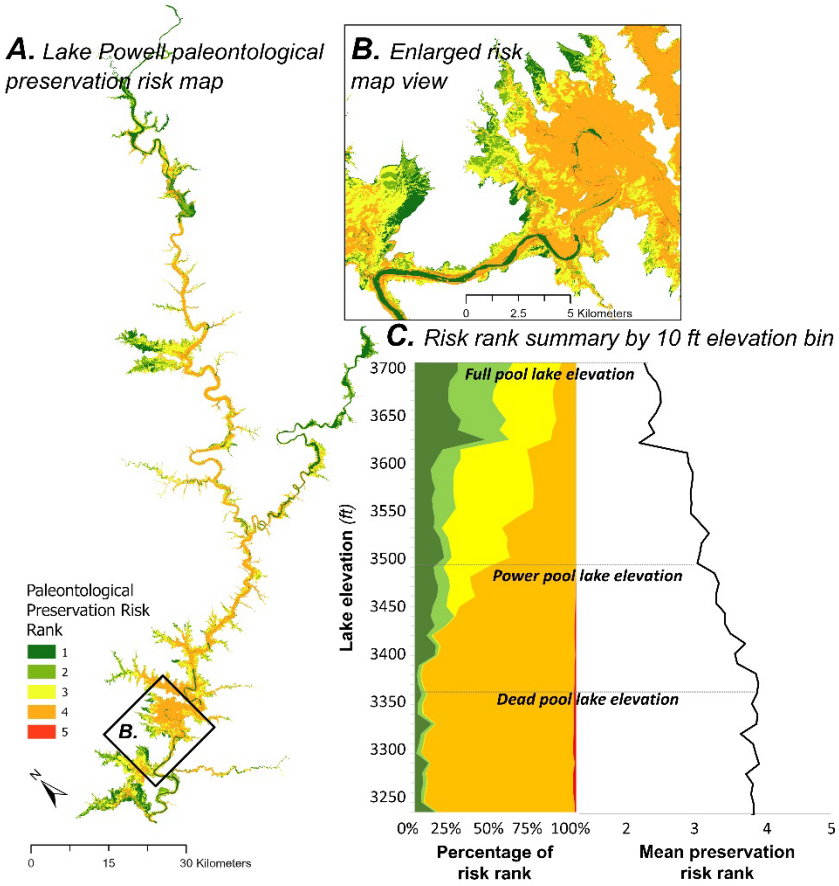
TA 12.2.2 Issue 1: How will fluctuations in water levels due to changes in dam operations (primarily in Lake Powell and Lake Mead) impact the exposure, erosion, and degradation of paleontological resources, including fossils and trackways?

The USGS, in cooperation with the NPS, created the Paleontological Preservation Hazard Model, which was used in the decision-making under the DMDU modeling process. This spatial model summarizes 10-foot-elevation bins in Lake Powell and 5-foot-elevation bins in Lake Mead, so that each elevation from full pool to empty has a preservation risk rank. Next, projected monthly lake elevations are related to those elevation bins to estimate the preservation risk rank. **Figure TA 12-3**, below, below depicts the relationship between lake elevation and preservation risk rank at Lake Powell (Caster et al. 2026). This relationship is consistent with general reservoir conditions; the same trend is true for Lake Mead (the risk rises as elevations fall).

As lake elevations decrease, paleontological preservation risk increases. The threshold for preservation risk at each reservoir was derived from the 90th percentile values of the 2008–2024 LTEMP. At Lake Powell, for example, the threshold is 2.93, which occurs at approximately 3,600-foot elevation. The more time that a risk rank is exceeded (in this case, the more time that lake elevations remain below 3,600 feet), the more paleontological resources that have likely never been exposed may become exposed. Those resources are subjected to higher preservation hazards than any time since the reservoir was filled.

Fluctuations in water levels due to changes in dam operations at Lake Powell and Lake Mead could significantly impact paleontological resources, particularly fossils and trackways found in sedimentary formations like sandstone. These resources are vulnerable to erosion, weathering, and degradation when exposed repeatedly as water levels rise and fall. Specific studies of paleontological sites and effects of inundation have not been conducted at Lake Powell or Lake Mead. Anecdotal evidence from field staff indicates that sandstone becomes friable and crumbly after periods of inundation and exposure. It is assumed that certain types of paleontological resources, especially trackways in softer bedrock such as sandstone, could be destroyed or severely affected by the inundation and exposure, resulting in loss of rock outcrop integrity. However, it is unclear whether greater damage is caused only by a single inundation event or by repeated cycles of inundation and exposure. It is assumed that paleontological resources, including fossils and trackways, will experience similar impacts as those paleontological resources subjected to similar processes.

Figure TA 12-3
Risk Rank Summary at Lake Powell



Source: Caster et al. 2026

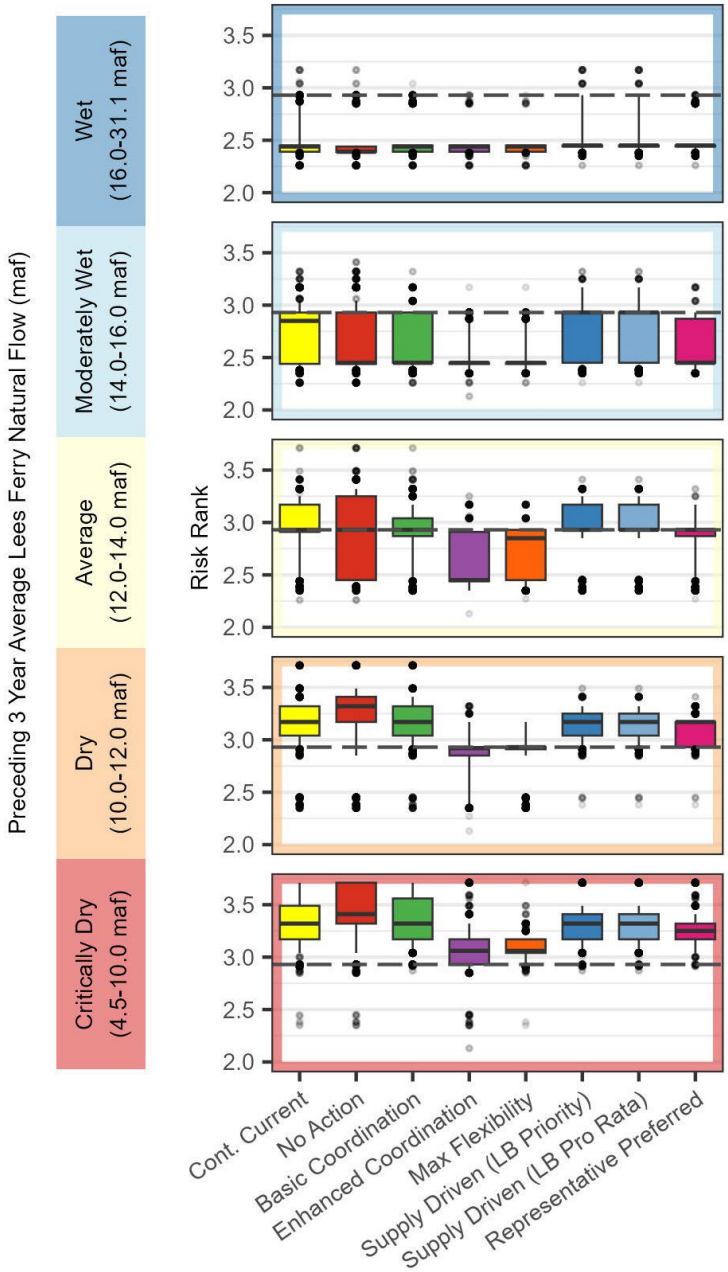
Lake Powell

This section presents a comparison of the No Action Alternative, Continued Current Strategies (CCS) Comparative Baseline, and action alternatives with respect to the paleontological preservation risk at Lake Powell. **Figure TA 12-4**, below, looks at the response of paleontological preservation risk in Lake Powell to different hydrologic conditions under different alternatives by looking at the preceding 3-year average of Lees Ferry natural flow. The figure presents the preservation risk rank values in a conditional box plot panel. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines. In each flow category shown in the box plot, the historically derived threshold is identified with a dashed line.

Note that the performance of the Supply Driven Alternative (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) will not differ for the Lake Powell preservation risk because they use the same operation of Lake Powell. See **Table TA 12-4** at the end of this technical appendix for the statistical breakdown of preservation risk rank at Lake Powell for each hydrologic condition and alternative, including the maximum, 90th percentile, 75th percentile, median, 25th percentile, 10th percentile, and minimum preservation risk rank.

In the Average Flow Category, the Maximum Operational Flexibility Alternative and Enhanced Coordination Alternative have similar ranges that are around or below the threshold. However, the Enhanced Coordination Alternative has a median risk value that is approximately 14 percent lower than what is modeled for the Maximum Operational Flexibility Alternative (2.45 and 2.85, respectively). In the Dry Flow Category, the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative perform similarly well, although all alternatives exceed the historically derived threshold under the Critically Dry Flow Category.

Figure TA 12-4
Water Year Maximum Paleontological Preservation Risk at Lake Powell



In all flow categories, the Basic Coordination Alternative has similar medians to the CCS Comparative Baseline and No Action Alternative. Under the Average Flow Category, the No Action Alternative has greater variability, while the Basic Coordination Alternative and CCS Comparative Baseline perform almost identically. All medians are at the historically derived threshold (see **Table TA 12-4**).

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) exceeds the historically derived threshold at the Average Flow Category and wetter conditions, with medians at or above 2.93. In the Wet Flow Category, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Basic Coordination Alternative, No Action Alternative, and CCS Comparative Baseline still have outliers that exceed the historically derived threshold. At Lake Powell, the Enhanced Coordination Alternative results in the least variability and most values below the threshold.

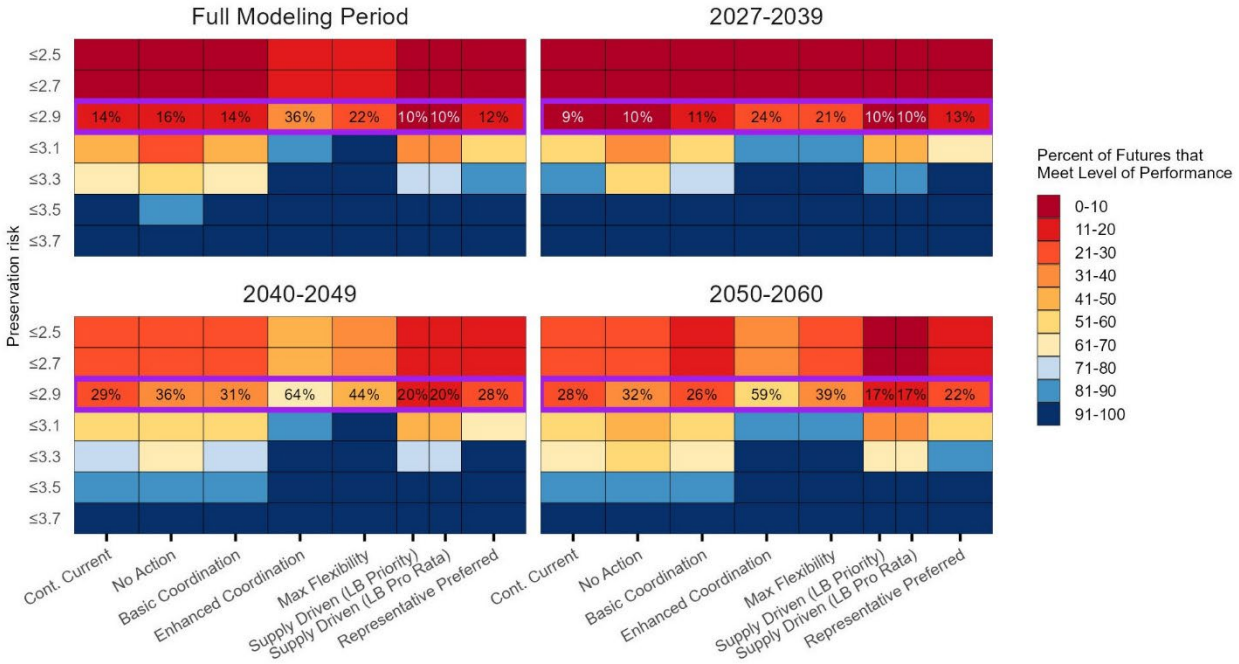
The Representative Preferred Alternative generally performs in the middle of the range of alternatives; it performs slightly better than the Supply Driven Alternatives and slightly worse than the Maximum Operational Flexibility Alternative. At Lake Powell, the Representative Preferred Alternative does not perform notably for preserving paleontological resources.

Figure TA 12-5, below, depicts the performance of each alternative with respect to keeping paleontological preservation risk ranks at Lake Powell below the historically derived threshold in at least 90 percent of months. This is the same threshold that what was used in **Figure TA 12-4**. The figure is broken into four heat maps, each showing a different time period during the analysis: the top left heat map shows the full modeling period from 2027 through 2060, and the remaining three panels show subperiods. Rows of the heat map show different preservation risk ranks, with higher rows corresponding to lower (more challenging) ranks. The highlighted row captures the percentage of futures that an alternative achieves a rank of 2.9 in 90 percent of the months (futures equal modeled hydrologic scenarios).

The Enhanced Coordination Alternative is the most robust at achieving a risk rank of 2.9 in 90 percent of months over the full modeling period, doing so in 36 percent of the futures. The Basic Coordination, No Action, and Representative Preferred Alternatives perform similarly to the CCS Comparative Baseline, succeeding in 14 percent, 16 percent, 12 percent, and 14 percent of futures, respectively. The Maximum Operational Flexibility Alternative succeeds 22 percent of the time over the full modeling period, which is just similar enough to the CCS Comparative Baseline and the No Action Alternative. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the least robust success rate over the full modeling period at 10 percent.

In lower rows of the heat maps, the Maximum Operational Flexibility Alternative begins to perform better as the preservation risk increases than the Enhanced Coordination Alternative; the Maximum Operational Flexibility Alternative consistently achieves 91–100 percent robustness by 3.1 and 3.3, respectively, over the full modeling period. The other alternatives reach 91–100 percent robustness at 3.5 while the CCS Comparative Baseline reaches 91–100 percent robustness at 3.7.

Figure TA 12-5
Paleontological Resources in Glen Canyon NRA: Robustness.
Percentage of Futures in Which Monthly Preservation Risk Stays Below the Value Specified in Each Row in at Least 90 Percent of Months

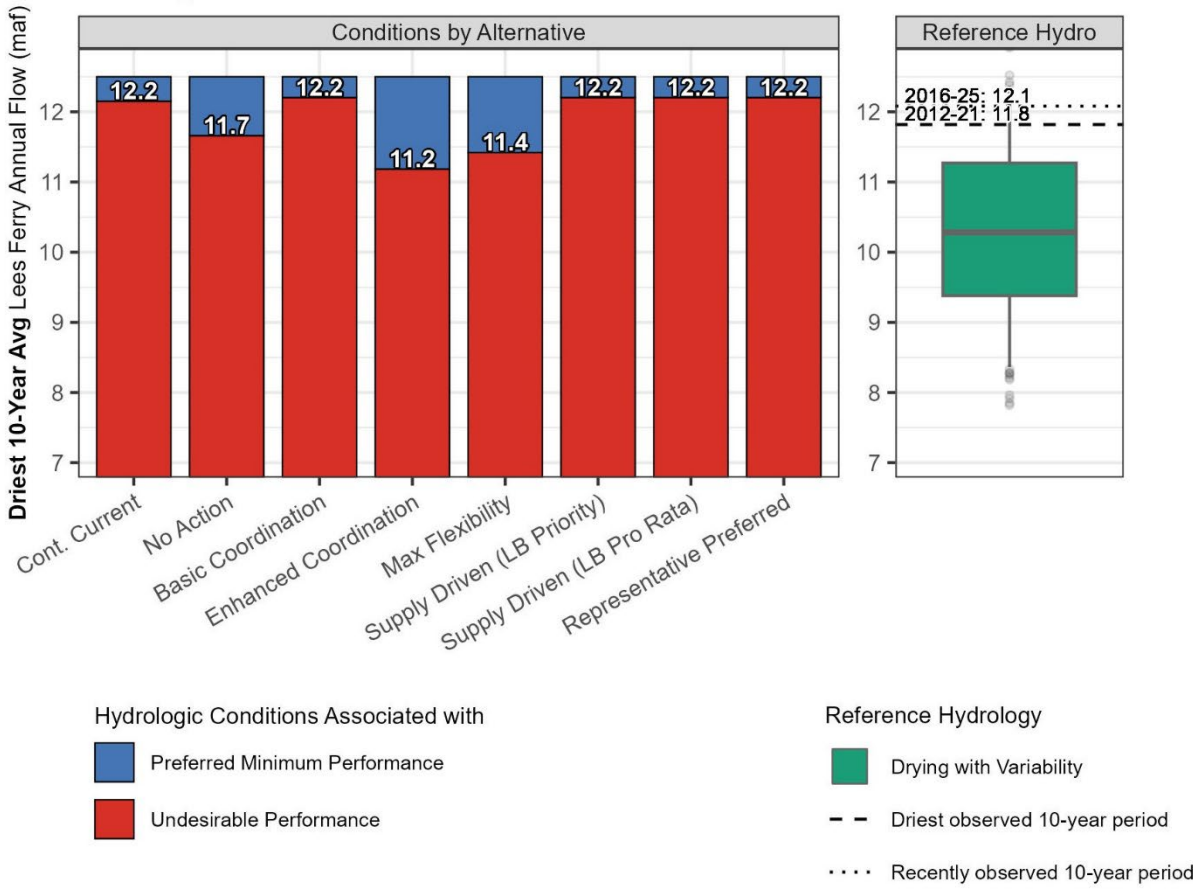


In the first decadal subperiod, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the historically derived threshold in 24 percent and 21 percent of futures, respectively. Given the planned length of this decision, it is notable that the Representative Preferred Alternative meets the historically derived threshold in only 13 percent of futures between 2027-2039. This suggests that existing challenges related to reservoir fluctuations at Lake Powell, including exposure, erosion, and degradation of paleontological resources, will continue under all alternatives.

Figure TA 12-6, below, looks at flow conditions that could cause the preservation risk rank to exceed the historically derived threshold in more than 10 percent of months of the 34-year modeling horizon. The driest 10-year average Lees Ferry natural flow was identified as a good predictor of undesirable performance; this is shown in the reference hydrology panel along with the recently observed 10-year average flow.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results in undesirable performance (that is, it becomes vulnerable to paleontological preservation risk rank exceeding the historically derived threshold), when the future includes a 10-year average flow of 12.2 maf or lower. Nearly all reference hydrologic traces include average flows of 12.1 or lower; the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results in futures where paleontological resources are most vulnerable to increased risk.

Figure TA 12-6
Paleontological Resources in Glen Canyon NRA: Vulnerability. Conditions that Could Cause Risk to Paleontological Sites in Lake Powell Exceeding Historical Benchmark More than 10 Percent of Months



The Enhanced Coordination Alternative results in undesirable performance when the 10-year average flow is below 11.2 maf. Approximately 75 percent of the reference hydrologic traces include averages this low or lower. The No Action Alternative and Maximum Operational Flexibility Alternative perform similarly to the driest 10-year average flow from 2012 to 2021 (11.7 maf and 11.4 maf, respectively). Under these alternatives, paleontological resources are vulnerable to conditions that are close to what has already occurred.

The CCS Comparative Baseline and the Basic Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives perform the same, with paleontological resources becoming vulnerable at approximately 12.2 maf. Nearly 100 percent of the reference hydrologic traces include average flows this low or lower, so the vulnerability is very high.

Lake Mead

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to paleontological preservation risk at Lake Mead. **Figure TA 12-7**, below, looks at the response of paleontological preservation risk in Lake Mead to different hydrologic conditions under different alternatives by looking at the preceding 3-year average of Lees Ferry natural flow. The figure presents the preservation risk rank values in a conditional box plot panel. The historically derived threshold at Lake Mead is a risk rank of 2.33. Note that the performance of the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) will not differ in Lake Mead preservation risk because the modeling assumes no banking activity. See **Table TA 12-5** at the end of this technical appendix for the statistical breakdown of preservation risk rank at Lake Mead for each hydrologic condition and alternative.

In each flow category shown in the box plot, the historically derived threshold (2.33) is identified with a dashed line. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) performs best in the Average Flow Category, with median preservation risk ranks and an interquartile range below the 2008-2024 defined threshold. The Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives perform similarly to one another, with median preservation risk ranks at or below the threshold and interquartile ranges that are mostly below the threshold. As the modeling enters the Critically Dry Flow Category, performance shifts to the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven Alternatives maintaining interquartile ranges below the threshold. Preservation risk ranks across all alternatives are above the threshold, with the Representative Preferred Alternative exhibiting the highest median. Large boxes on the plot represent more uncertainty as to how conditions might change, and the larger the section of the box that is above the threshold line, the more resources that are being exposed to risks they have not faced since Lake Mead was filled.

For all hydrology except the Critically Dry Flow Category, the Maximum Operational Flexibility Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform similarly with a median preservation risk around, or just above, the historical threshold. The Maximum Operational Flexibility Alternative appears to have slightly less variability with a smaller interquartile range, though a larger percentage of the range is above the historical threshold. The Enhanced Coordination Alternative has a slightly larger median preservation risk rank but a smaller interquartile range, suggesting less variability in results but more certainty of the preservation risk exceeding historical conditions. Under the driest conditions, all alternatives have a moderately strong chance of exceeding the historical preservation risk conditions.

At Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results in the least variability and most values below the threshold. The Representative Preferred Alternative performs generally in the middle of the alternatives, suggesting that preservation risk ranks will exceed historical conditions over the planned length of the decision.

Figure TA 12-7
Water Year Maximum Paleontological Preservation Risk at Lake Mead

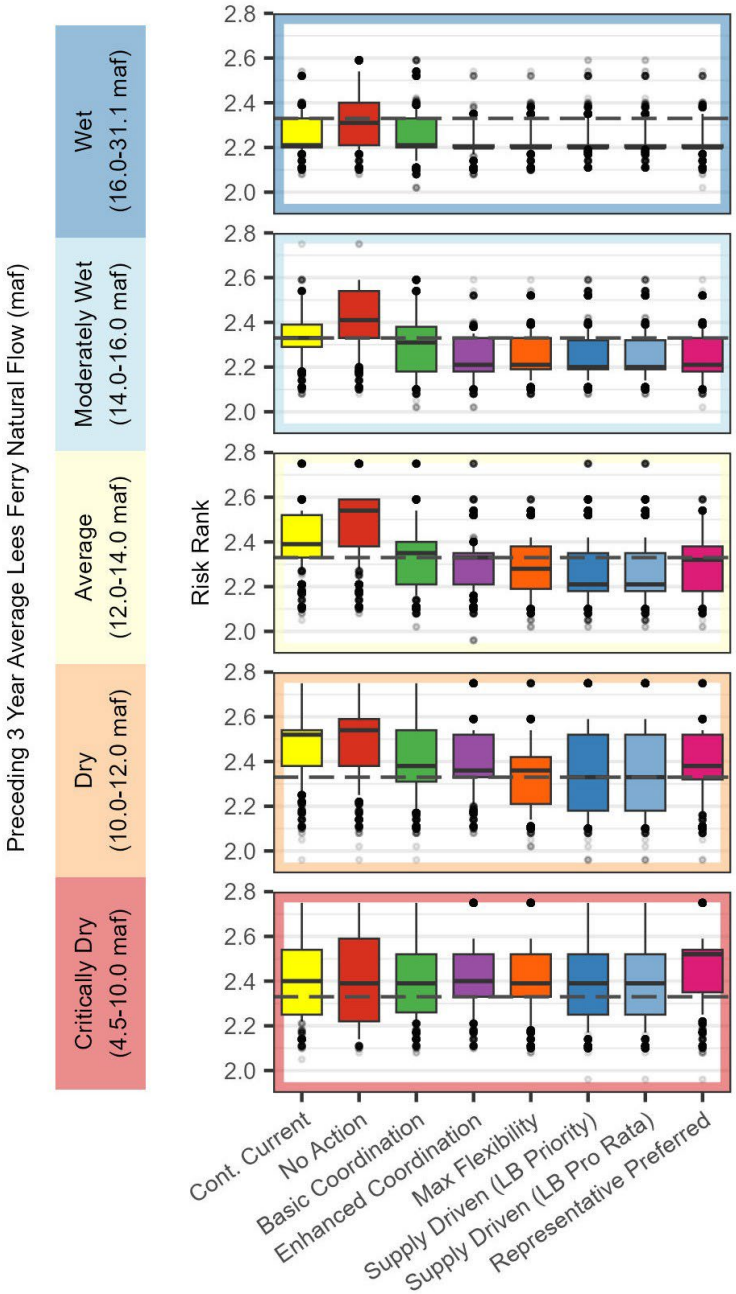
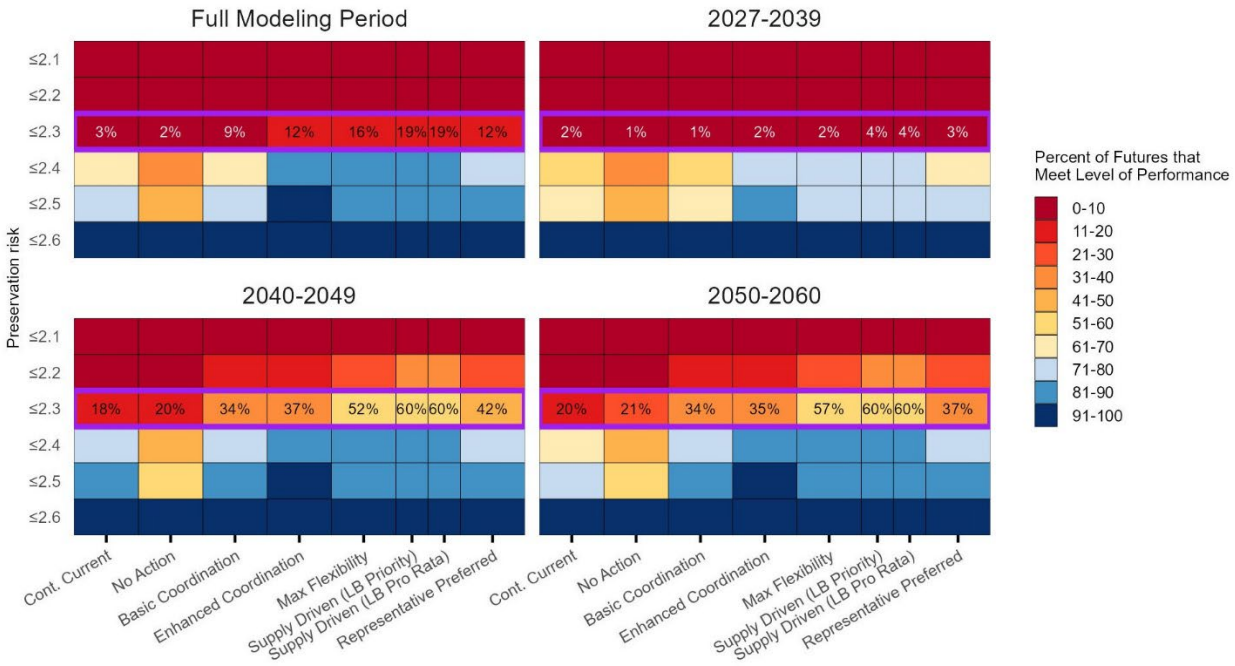


Figure TA 12-8, below, depicts the performance of each alternative with respect to keeping paleontological preservation risk ranks at Lake Mead below the historically derived threshold in at least 90 percent of months. This is the same threshold as what was used in **Figure TA 12-7**. The figure is broken into four heat maps, each showing a different time period during the analysis. The top left heat map shows the full modeling period from 2027 through 2060, and the remaining three panels show subperiods. Rows of the heat map show different preservation risk ranks, with higher

rows corresponding to lower (more challenging) ranks. The highlighted row captures the percentage of futures that an alternative achieves a rank of 2.3 in 90 percent of the months.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust at achieving a risk rank of 2.3 in 90 percent of months over the full modeling period, doing so in 19 percent of the futures. The Maximum Operational Flexibility Alternative performs similarly to the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), achieving a risk rank of 2.3 in 16 percent of futures. The No Action Alternative and CCS Comparative Baseline are the least robust and perform identically, succeeding in 2 percent and 3 percent of futures, respectively; the Representative Preferred Alternative and Enhanced Coordination Alternative perform the same (12 percent successful futures). In lower rows of the heat map, the Enhanced Coordination Alternative achieves 91–100 percent robustness by 2.5. The CCS Comparative Baseline and all other alternatives achieve 91–100 percent robustness at 2.6.

Figure TA 12-8
Paleontological Resources in Lake Mead NRA: Robustness. Percentage of Futures in Which Monthly Preservation Risk Stays Below the Value Specified in Each Row in at Least 90 Percent of Months



Robustness of the alternatives does not immediately improve when analyzing shorter modeling periods. In the 2027–2039 period, robustness of the CCS Comparative Baseline and all action alternatives drop; the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) drops more than 10 percent, from 19 percent in the full modeling period to 4 percent in the 2027–2039 decadal subperiod. Given the planned length of the decision, it is notable that the Representative Preferred Alternative is robust in only 3 percent of futures between 2027 and 2039,

suggesting that reservoir fluctuations in Lake Mead will result in exposure, erosion, and degradation of paleontological resources at rates greater than historically observed.

Robustness quickly improves in the 2040–2049 and 2050–2060 subperiods. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust in 2040–2049, with 60 percent of futures achieving a risk rank of 2.3 in 90 percent of months. However, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is slower to improve performance in the lower rows; the Enhanced Coordination Alternative reaches 91–100 percent robustness at 2.5. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) reaches 91–100 percent robustness at 2.6.

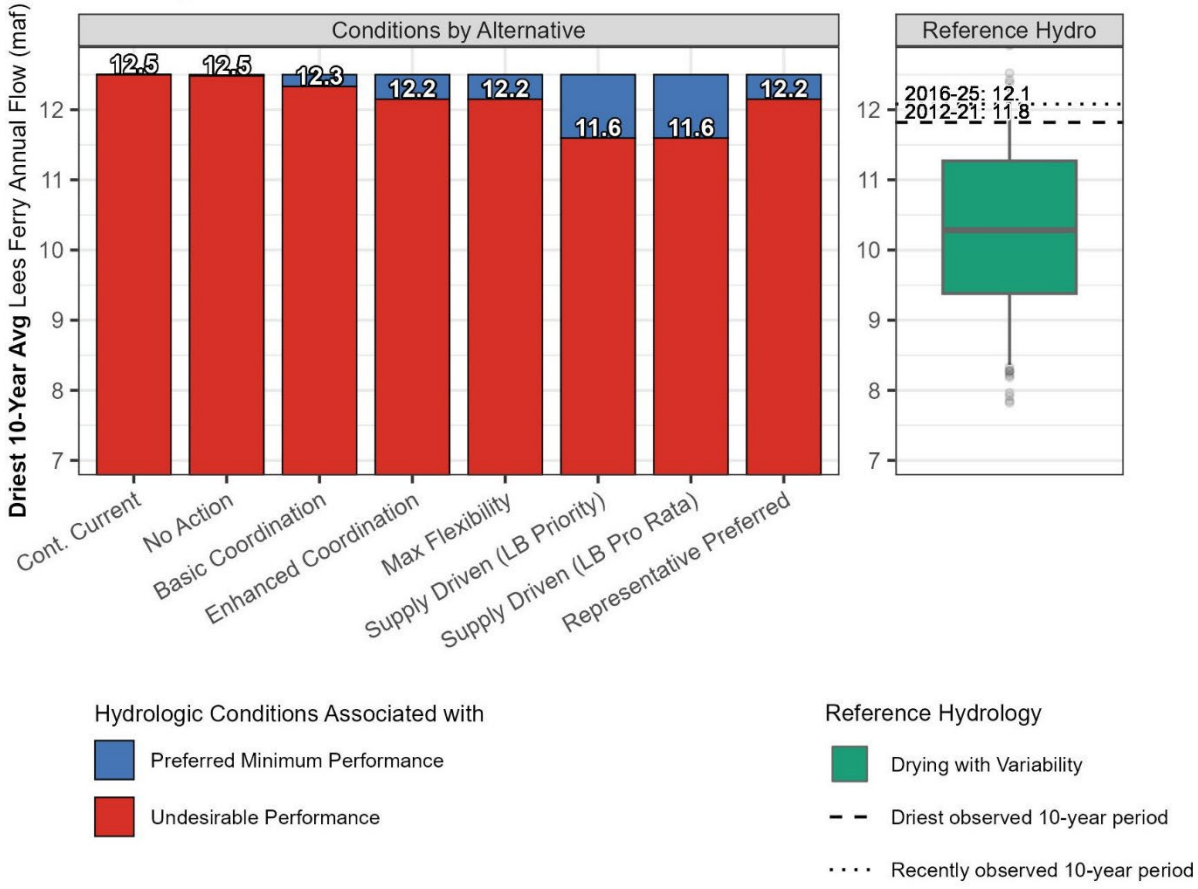
In the 2050–2060 subperiod, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) continues to perform best with respect to the historically derived threshold. However, the Enhanced Coordination Alternative reaches 91–100 percent robustness at 2.5. At the historically derived threshold, the Maximum Operational Flexibility Alternative is more robust than the Enhanced Coordination Alternative (57 percent and 35 percent, respectively). However, the Enhanced Coordination Alternative is faster to achieve 91–100 percent robustness. Overall, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust alternative at Lake Mead in the 2050–2060 subperiod, achieving 90 percent of months where the historically derived threshold is met in 60 percent of futures. The Representative Preferred Alternative continues to perform generally in the middle of the alternatives at Lake Mead.

Figure TA 12-9, below, looks at flow conditions that could cause the preservation risk rank at Lake Mead to exceed the historically derived threshold in more than 10 percent of months of the 34-year modeling horizon. The driest 10-year average Lees Ferry natural flow was identified as a good predictor of undesirable performance; this is shown in the reference hydrology panel along with the driest and recently observed 10-year period.

Paleontological resources are the most vulnerable to risk under the CCS Comparative Baseline and No Action Alternative. Undesirable performance occurs at 12.5 maf; nearly 100 percent of the reference hydrology traces include average flows of 12.5 maf or lower. These two scenarios are vulnerable to conditions that have already occurred; average flows of 11.8 maf occurred during the driest observed 10-year period. The Basic Coordination Alternative and Enhanced Coordination Alternative are vulnerable to increased risk to paleontology sites at flows of 12.3 maf and 12.2 maf, respectively. Under all alternatives where the undesirable performance is greater than 12.1 maf, vulnerability is nearly certain.

The Maximum Operational Flexibility and Representative Preferred Alternatives result in undesirable performance if the future includes a driest 10-year flow of 12.2 maf, which is the greater than the 2012–2021 driest observed flow. Under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), paleontological resources become vulnerable to risk at flows of 11.6 maf. Approximately 75 percent of reference hydrology traces are drier than 11.6 maf, so the vulnerability is considered high. It is notable that under the Representative Preferred Alternative, paleontological resources in Lake Mead would be vulnerable to exposure, erosion, and degradation when flows are 12.2 maf or less.

Figure TA 12-9
Paleontological Resources in Lake Mead NRA: Vulnerability.
Conditions that Could Cause Risk to Paleontological Sites in Lake Mead Exceeding Historical Benchmark More than 10 Percent of Months



Summary Comparison of Alternatives

Lake Powell and Lake Mead

Continuous inundation preserves paleontological resources better than repeated exposure to waves and wet-dry cycles. Changes in lake elevations that may expose previously inundated paleontological resources are the biggest concern; the Paleontological Preservation Risk Model uses lake elevations to establish risk. For Lake Powell, the Enhanced Coordination Alternative performs best with regard to meeting the paleontological preservation risk rank threshold in all hydrologic conditions except the Critically Dry Flow Category; this alternative is followed by the Maximum Operational Flexibility Alternative. Both alternatives exhibit median risk ranks that are at or below the threshold. The Basic Coordination Alternative is the least effective action alternative with regard to meeting the paleontological preservation risk threshold. This alternative becomes successful at the Moderately Wet Flow Category but consistently exceeds the threshold at the Average Flow Category and drier. The No Action Alternative and CCS Comparative Baseline perform similarly to the Basic Coordination Alternative.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and Maximum Operational Flexibility Alternative perform similarly and produce median preservation risk rank around, or just above, the historically derived threshold in all hydrologic conditions except the Critically Dry Flow Category. All alternatives exceed historical preservation risk conditions under the Critically Dry Flow Category.

For both Lake Powell and Lake Mead, the Representative Preferred Alternative generally performs somewhere in the middle of the action alternatives, never outperforming all alternatives in terms of paleontological resource risk reduction. Given the length of the planned decision, it is notable that paleontological preservation risk will likely be heightened under the Representative Preferred Alternative, as more resources will become exposed and eroded due to fluctuating reservoir levels and flows.

Under the Maximum Operational Flexibility Alternative, the paleontological preservation risk rank would be maintained at or below the threshold of significance for the most amount of time across both reservoirs. Paleontological resources that are inundated by lake elevations would not be exposed to erosion, degradation, and the repeated cycles of inundation and exposure and wave action. The Maximum Operational Flexibility Alternative would be a balanced approach minimizing preservation risk. The Enhanced Coordination Alternative would also maintain paleontological preservation risk rank in the reservoirs, but not as consistently as under the Maximum Operational Flexibility Alternative.

TA 12.2.3 Issue 2: How will altered sediment transport, including both fluvial and aeolian deposition patterns, affect the preservation and stability of paleontological resources?

The preservation and stability of paleontological resources along the Colorado River corridor are closely tied to sediment dynamics, particularly the deposition and redistribution of fine sediments through fluvial and aeolian processes. Sediment burial helps protect surface-exposed resources from erosion, weathering, and human disturbance, while changes in the magnitude or timing of sediment delivery may either enhance or degrade preservation conditions. However, increased exposure of sandbars and sediment surfaces typically heightens the risk of erosion, weathering, and loss of fossil integrity, while sediment deposition and rapid burial may provide temporary protection from degradation. Frequent fluctuations in the water level that alternately expose and inundate sediments are generally detrimental to long-term preservation.

Fluvial Sediment Transport

Figure TA 12-10 depicts the performance of each alternative with respect to the fraction of total sand mass transported by sandbar-forming flows, defined as releases greater than 37,000 cubic feet per second (cfs), over the 34-year modeling horizon. As detailed in **TA 5**, Geomorphology and Sediment, HFE releases represent Reclamation's primary tool for managing the limited sediment resources and maintaining or increasing sandbar size. These controlled floods, which range from approximately 31,500 cfs to over 37,000 cfs, are the only mechanism capable of producing widespread sandbar building (Hazel et al. 2022; Salter et al. 2025). Sandbars erode between HFE releases (Hazel et al. 2022), with the highest rates immediately after a flood (when bars have the most sediment available for erosion) and decreasing with time (Grams et al. 2010). Steadier flows erode bars at a lower rate than fluctuating flows (Wright et al. 2008).

Figure TA 12-10
Sand-Load Index: Robustness.
Percentage of Futures in Which the Fraction of Sand Mass Transported Above 37,000 cfs is the Value Specified in Each Row

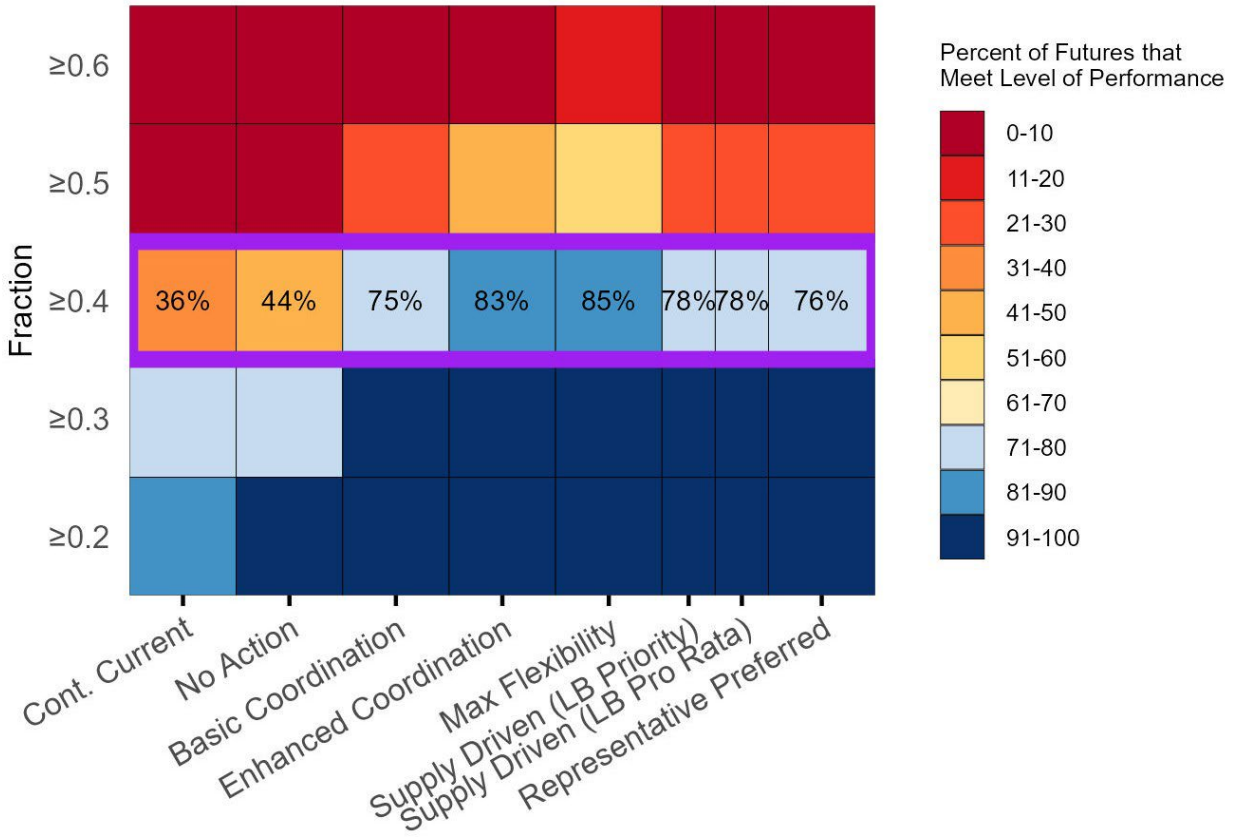


Figure TA 12-10 evaluates how robustly each alternative supports sandbar formation by showing the percentage of futures in which at least 40 percent of total sand mass is transported during sandbar-forming flows. This 40 percent threshold was selected as an indicator of conditions likely to support adequate sand deposition to retain sandbars. Due to modeling constraints, this figure only depicts robustness for the entire modeling period and does not include decadal subperiods.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives exhibit the highest robustness; each achieves successful outcomes—defined as meeting or exceeding the 40 percent threshold—in 83 percent and 85 percent of futures, respectively. Under these alternatives, sediment transport dynamics would generally support sandbar deposition at satisfactory levels, which would indirectly result in desirable levels of sand for fossil reburial.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) meets the threshold in 78 percent of futures, while the Representative Preferred and Basic Coordination Alternatives perform moderately lower at 76 percent and 75 percent, respectively. These three alternatives perform similarly to the Enhanced Coordination and Maximum Operational Flexibility Alternatives because their robustness is within 10 percent of each other, and all five action alternatives reach 91-100 percent robustness within one row of the heatmap. It is notable that the Representative

Preferred Alternative meets the threshold similarly to the highest performing alternative, indicating that sandbar building would continue to occur at rates beneficial to fossil reburial.

Under both the No Action Alternative and the CCS Comparative Baseline, fewer than half of futures meet the 40 percent sandbar-forming flow threshold, with the CCS Comparative Baseline exhibiting the lowest success rate of all alternatives. These outcomes indicate that sand would be transported at rates less favorable for sandbar building and that fossils would be at greater risk of exposure during the erosion of sandbars and less frequently buried during sandbar-building events under the No Action Alternative.

Aeolian Sediment Transport

As discussed above in **Section TA 12.2.1**, Methodology, the aeolian transport model looks at favorable conditions for wind-borne sand to be present to protect paleontological resources over long periods of time using projected vegetation cover and exposed sand area or sandbar volume (Kelley et al. 2026). The vegetation and sandbar volume modeling used is from the Marble Canyon sub-reach from Lees Ferry to the Little Colorado River. The exposed sand modeling was conducted for the portion of the river from Lees Ferry to Bright Angel Creek. But the general conclusions are pertinent to the entire river.

The results of the annual vegetation cover modeling are presented in **Section TA 9**, Vegetation Including Special Status Species. Overall, less vegetation is better for aeolian sand transport because it leaves sand exposed to be picked up by the wind. As discussed in **Section TA 9.2.2** and seen in **Figure TA 9-13**, for all modeled scenarios under the wet and moderately wet conditions, there would be less vegetation cover (below observed conditions) from higher water levels and longer HFEs. As conditions grow drier, water flows diminish, HFEs are shorter, and vegetation cover increases (see **Figure TA 9-13**).

For the Average Flow Category, the median for the CCS Comparative Baseline, the No Action Alternative and all action alternatives (including the Representative Preferred Alternative) is at or just below the modeled historical conditions (i.e., the 2007 Interim Guidelines period [WY 2008–2025]) and the interquartile ranges are relatively small. This indicates that the annual total vegetation may be similar to historical conditions under average flows. Conversely, under the dry and critically dry conditions, annual total vegetation cover increases and differentiation between alternatives can be seen. For the Critically Dry Flow Category, the medians and interquartile ranges are above the modeled historical conditions (dashed line) for all sub-reaches and all alternatives except the interquartile range for the CCS Comparative Baseline, which drops just below the dashed line (see **Figure TA 9-14** in **TA 9**). This indicates that there may be more annual total vegetation cover, especially under critically dry flows.

The results of the sandbar volume modeling are presented in **TA 5**, Geomorphology and Sediment. As discussed in **TA 5**, for an HFE to be triggered, enough sand needs to be available in Marble Canyon and enough water needs to be available in Lake Powell (as measured by water level), with both the required amounts of sand and water being dependent on the selected HFE duration. Additionally, HFE releases can only be implemented when Lake Powell water levels are 3,500 feet, with sandbar deposition occurring most rapidly during the first 4 days of an HFE event. Lastly,

sandbar volume modeling uses the assumption that HFEs are implemented as often as possible (see **Section TA 5.2.1**, Modeling Criteria and Assumptions). For the aeolian transport model, increased exposed sandbar volume (or the amount of "useable" sand) means more sand is available to protect paleontological resources. In general, as conditions get drier and the amount of water flowing through the river decreases, exposed sandbar volume increases (see **Section TA 5.2.4**, Issue 4: Sandbar Volume, in **TA 5**, Geomorphology and Sediment). Differences in performance among the alternatives also increase as hydrological conditions become drier, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives performing the best for the Critically Dry Flow Category (see **Figure TA 5-12** in **TA 5.2.5**).

Figure TA 12-11 shows the results of the water year average of exposed sand area modeling, with the 90th percentile and median (50th percentile) of modeled sand areas depicted as the two dashed lines. As with exposed sandbar volume, increased exposed sand area is beneficial for the aeolian transport of sand to protect paleontological resources. In the Average Flow Category, the median exposed sand area is around the 90th percentile (upper dashed line) and the median (50th percentile, lower dashed line) of modeled sand area (in million square meters). As conditions become drier, all modeled scenarios perform similarly with the forecasted median exposed sand area above the observed median with the Enhanced Coordination Alternative having a slighter higher median than the action alternatives. In the Critically Dry Flow Category, the Maximum Operational Flexibility Alternative exhibits the most variability with the greatest interquartile range. The Representative Preferred Alternative generally performs in the middle of the action alternatives, indicating that the exposed sand area will be conducive to the protection of paleontological resources through aeolian transport.

Figure TA 12-12 shows the results of the aeolian sand modeling, in which the percentage of futures meet one of two criteria: either the annual sand volume is greater than the median observed sand volume over the last 20 years and the vegetation cover area is less than the median observed area over the last 20 years, or the sandbar volume is greater than 1.5 times the initial condition. The highlighted row shows when those conditions are met at least 1 out of every 3 years, which is the optimal time frame for enough sand to be available for aeolian transport, based on previous studies.

Over the full modeling period, the Enhanced Coordination and the Maximum Operational Flexibility Alternatives are the most robust; they meet the desired conditions of at least 1 out of every 3 years in 19 percent and 18 percent of futures, respectively, followed by the No Action Alternative only in 14 percent of futures. The Basic Coordination Alternative meets the preferred minimum of performance in only 9 percent of futures, with the Representative Preferred Alternative meeting it in only 6 percent of futures. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the least robust, meeting the desired conditions in only 3 percent of futures. If the year interval is lengthened (that is, to 1 out of 4, 5, or 6 years), the models perform in a similar overall pattern; the Enhanced Coordination and the Maximum Operational Flexibility Alternatives perform the best.

Figure TA 12-11
Water Year Average of Exposed Sand Area

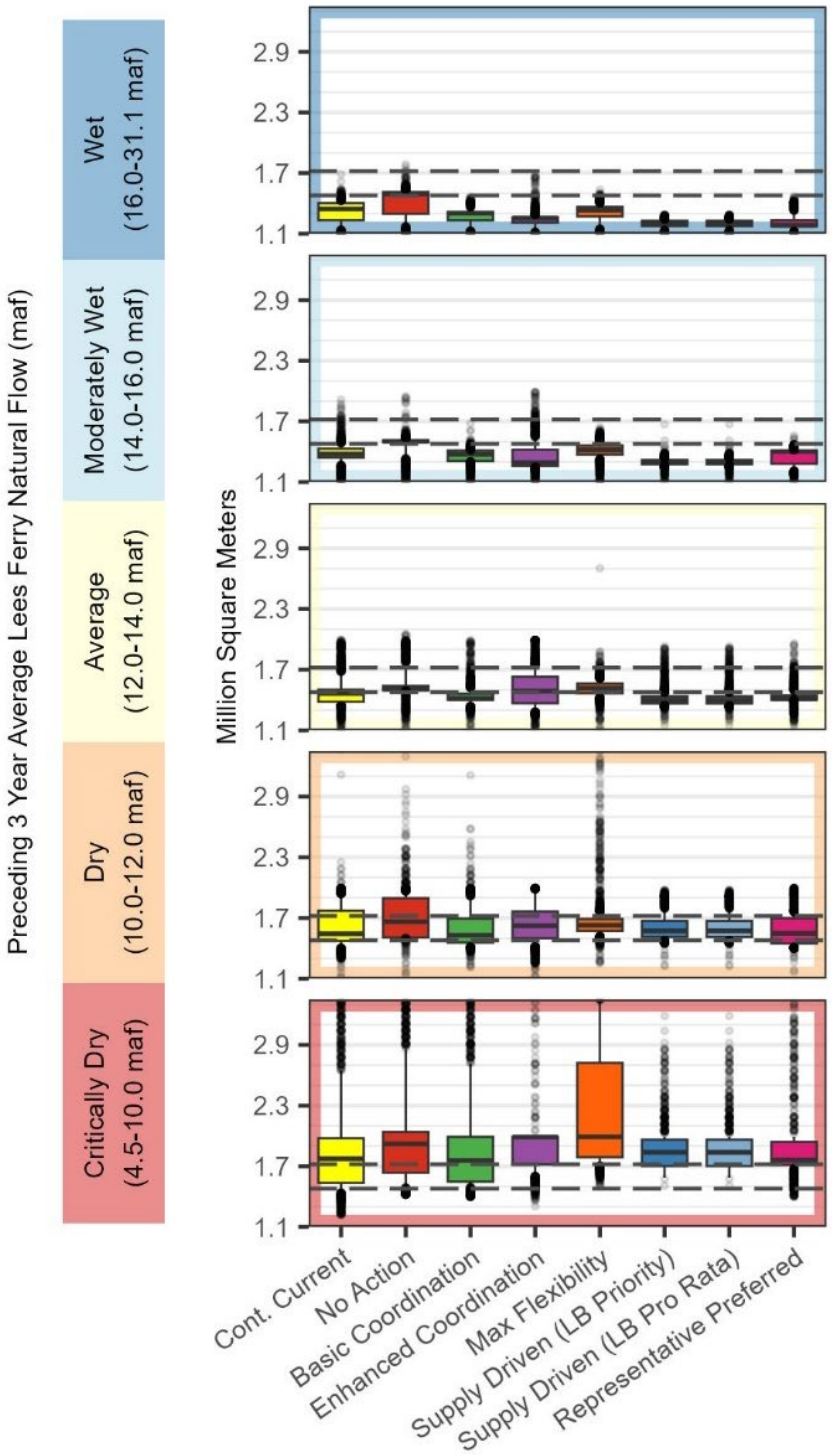


Figure TA 12-12
Multi-modal Aeolian Transport Condition: Robustness.
Percentage of Futures in Which Annual Sand Area Is >50th Percentile and Vegetation Cover Is <50th Percentile, or Sandbar Volume Is >1.5 Times the Initial Condition in the Frequency Specified in Each Row



It is notable that the Representative Preferred Alternative meets the desired conditions in 17 percent of futures between 2027 and 2039, indicating that the conditions required for aeolian transport will not occur frequently, exposing paleontological resources to erosion and other weathering mechanisms.

When results are split over intervals from 2027–2039, 2040–2049, and 2050–2060, the percentage of futures meeting the desired conditions increase for both the Enhanced Coordination and the Maximum Operational Flexibility Alternatives from 35 percent to 55 percent and 53 percent and from 30 percent to 57 percent and 56 percent, respectively. These results seem to indicate an increase in acceptability over time, which may correlate to increased available sand over time; however, the perceived increase is driven by an increase in sandbar volume over time in the modeling, with the understanding that HFEs would continue as planned. In reality, the decision to conduct HFEs depends on annual review.

Summary Comparison of Alternatives

Fossils and other paleontological resources that become exposed to oxygen, wind, and erosion are vulnerable to degradation. Sediment transport, by both aeolian and fluvial processes, can better preserve paleontological resources through burial. Changes in river flows and HFEs can affect the amount of sediment available for transport and indirectly impact the stability and preservation of fossils and other paleontological resources.

Based on the modeling, the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative were the most robust for sand transport during HFEs. Under these alternatives, the rate of sand transport would generally support sandbar building and indirectly contribute to the burial and preservation of paleontological resources. In contrast, the No Action Alternative was the least robust, and HFEs would not support sandbar building in more than 44 percent of futures.

The Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative were also the most robust for aeolian transport of sediment. Although the robustness modeling results showed only 19 and 18 percent of successful futures for these alternatives, respectively, the Basic Coordination Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) produced values of 9 percent or lower.

The Representative Preferred Alternative generally performs in the middle of the action alternatives, never outperforming the best alternative with regard to paleontological resources. This means that paleontological resources will be vulnerable to altered fluvial and aeolian sediment transport, particularly between 2027 and 2039. Paleontological resources are likely to be exposed rather than buried, and may be degraded by multiple weathering mechanisms over time.

The river corridor, from below Hoover Dam to the SIB, is not well mapped by PFYC. Classifications in the corridor are mostly PFYC W (water). While possible, the presence or impacts on scientifically important vertebrate fossils are not anticipated within the river corridor when compared with the potential for known or undiscovered fossils in the reservoirs. The Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative are the most robust alternatives with regard to sediment transport in the river corridor. Sediment transport would indirectly preserve and stabilize the known and unknown fossil localities.

TA 12.2.4 Issue 3: How will adjustments to dam operations and water levels alter human access to newly exposed fossil sites, and what are the potential risks of increased disturbance, unauthorized collection, and recreational impacts on paleontological resources?

The Paleontological Preservation Risk Model does not include the indirect impacts of human disturbance. However, the model does correlate with lake elevations at Lake Powell and Lake Mead. As lake elevations drop, more of the reservoir becomes accessible to visitors, particularly in flatter areas that are easy to access. The longer amount of time lake elevations remain low, the more vulnerable paleontological resources become to increased rates of disturbance, unauthorized collection, and recreational impacts. The DMDU analysis used for lake elevations in **TA 3**, Hydrologic Resources, is used in conjunction with the paleontological preservation risk to conduct the analysis of indirect impacts on paleontological resources from the alternatives.

Lake Powell

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to increased disturbance of, unauthorized collection of, and recreational impacts on paleontological resources at Lake Powell. For a more detailed analysis of

recreation at Lake Powell, please refer to **TA 14**, Recreation. For a more detailed analysis of hydrologic conditions at Lake Powell, please refer to **TA 3**, Hydrologic Resources.

The alternatives perform similarly with respect to maintaining lake elevations and achieving desirable paleontological preservation risk ranks. The Maximum Operational Flexibility Alternative and Enhanced Coordination Alternative are the most robust at staying above 3,500-foot elevation in 100 percent of months over the full modeling period, doing so in 86 percent and 74 percent of futures, respectively. This result is similar to the robustness of both alternatives with regard to achieving the historically derived preservation risk threshold in 90 percent of months.

The No Action Alternative is the least robust at maintaining 3,500-foot elevation in 100 percent of months, doing so in 4 percent of futures over the full modeling period. The No Action Alternative is only 61–70 percent robust at maintaining this elevation in 60 percent of months. The CCS Comparative Baseline, Basic Coordination Alternative, and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform similarly, maintaining the 3,500-foot elevation in 100 percent of months in 18 percent, 13 percent, and 18 percent of futures, respectively.

The Representative Preferred Alternative meets this robustness criteria in 28 percent of modeled futures in the full modeling period. Based on the planned length of this alternative, it is important to note that it meets the preferred minimum performance level in 49 percent of futures between 2027 and 2039. The Representative Preferred Alternative is much less robust than the Maximum Flexibility and Enhanced Coordination Alternatives, but it is much more robust than all other alternatives and the CCS Comparative Baseline.

Alternatives that keep Lake Powell at or above 3,500 feet more often will keep most sites below that level underwater (and protected) more of the time. Therefore, the risk of human disturbance would be for resources above 3,500 feet. The preservation risk rank's historically derived threshold is achieved at approximately 3,500-foot elevation at Lake Powell. Under the Maximum Operational Flexibility Alternative, elevations at Lake Powell would be most consistently at or above 3,500 feet, which would result in the inundation of the most paleontological resources and the least amount of shoreline expansion for visitors to access resources.

Lake Mead

This section presents a comparison of the No Action Alternative, CCS Comparative Baseline, and action alternatives with respect to increased disturbance of, unauthorized collection of, and recreational impacts on paleontological resources at Lake Mead. For a more detailed analysis of recreation at Lake Mead, please refer to **TA 14**, Recreation. For a more detailed analysis of hydrologic conditions at Lake Mead, please refer to **TA 3**, Hydrologic Resources.

The alternatives perform similarly with respect to maintaining lake elevations and achieving desirable paleontological preservation risk ranks. The Supply Driven Alternative (LB Pro Rata) and Maximum Operational Flexibility Alternative are similarly robust at keeping Lake Mead elevation above 975 feet in 100 percent of months, doing so in 73 percent and 70 percent of futures, respectively. The Enhanced Coordination Alternative and Supply Driven Alternative (LB Priority) are also similarly

robust, maintaining Lake Mead elevation above 975 feet in 65 percent and 61 percent of futures, respectively.

The Representative Preferred Alternative meets this robustness criteria in 50 percent of modeled futures in the full modeling period. Based on the planned length of this alternative it is important to note that it meets the preferred minimum performance level in 66 percent of futures between 2027 and 2039.

The No Action Alternative is the least robust, keeping Lake Mead elevation above 975 feet in 100 percent of months in 21 percent of futures over the full modeling period. Robustness of the CCS Comparative Baseline is 38 percent; robustness of the Basic Coordination Alternative is 50 percent.

Summary Comparison of Alternatives

Lake Powell and Lake Mead

Changes in dam operations that lower reservoir levels can expand the extent of exposed shorelines and channel margins, increasing human access both by land and by small watercraft. Recreational activities such as off-highway vehicle use, hiking, camping, and boating at and around the reservoirs can inadvertently disturb fragile paleontological materials through trampling, erosion from trail formation, or sediment displacement. Additionally, unauthorized fossil collection, either intentional or opportunistic, may increase as new sites become visible and accessible to the public. Once displaced or removed, contextual information critical for scientific study and resource management may be lost.

Increased public presence also raises the likelihood of secondary impacts, such as looting, vandalism, or inadvertent exposure through surface collection. These impacts are particularly concerning in areas lacking monitoring or signage that would otherwise deter unauthorized activities. Conversely, rapid reburial of exposed sites during subsequent water level rises may offer temporary protection from ongoing disturbance, although repeated exposure and burial cycles can weaken fossil integrity over time.

Under the Maximum Operational Flexibility Alternative, the paleontological preservation risk rank would be maintained at or near the historically derived threshold in both Lake Powell and Lake Mead. Additionally, critical lake elevations would be maintained at 3,500 feet in Lake Powell and 975 feet in Lake Mead in 87 percent and 80 percent of futures, respectively. The operations proposed under the Maximum Operational Flexibility Alternative would result in the least amount of time paleontological resources below critical elevations are exposed to human disturbance and associated impacts.

Under the Representative Preferred Alternative, critical lake elevations would be maintained at 3,500 feet in Lake Powell and 975 feet in Lake Mead 28 percent and 50 percent of futures, respectively. The operations proposed under the Representative Preferred Alternative only result in better conditions for the preservation of paleontological resources when compared with the CCS Comparative Baseline, No Action Alternative, and the Basic Coordination Alternative in both reservoirs.

The Basic Coordination Alternative would result in greater stretches of time where the paleontological preservation risk threshold is exceeded, and greater stretches of time where lake

elevations drop below critical thresholds. This would result in increased accessibility to vulnerable paleontological sites, and more opportunities for human disturbance.

Management challenges include identifying and monitoring newly exposed areas in real time, implementing site protection measures (such as signage, education, and enforcement), and coordinating with agencies and research institutions to document and recover significant finds before they are lost. Adaptive management strategies—such as targeted public outreach, remote sensing, and rapid site assessment protocols—could mitigate potential damage while accommodating necessary operational changes to the dams.

Statistical Summary Tables

Table TA 12-4
Water Year Maximum Paleontological Preservation Risk at Lake Powell

Alternative	Flow Category (maf)	Max	90th percentile	75th percentile	Median	25th percentile	10th percentile	Min
CCS Comparative Baseline	16.0–31.11	3.17	**2.85**	**2.45**	**2.44**	**2.39**	**2.39**	**2.26**
CCS Comparative Baseline	14.0–16.0	3.32	3.04	2.93	**2.85**	**2.44**	**2.39**	**2.26**
CCS Comparative Baseline	12.0–14.0	3.71	3.25	3.17	2.93	**2.91**	**2.45**	**2.26**
CCS Comparative Baseline	10.0–12.0	3.71	3.32	3.32	3.17	3.04	**2.92**	**2.35**
CCS Comparative Baseline	4.46–10.0	3.71	3.71	3.49	3.32	3.17	3.04	**2.35**
No Action	16.0–31.11	3.17	**2.45**	**2.44**	**2.39**	**2.39**	**2.39**	**2.26**
No Action	14.0–16.0	3.41	3.04	2.93	**2.45**	**2.44**	**2.39**	**2.26**
No Action	12.0–14.0	3.71	3.32	3.25	2.93	**2.45**	**2.44**	**2.26**
No Action	10.0–12.0	3.71	3.49	3.41	3.32	3.17	**2.85**	**2.35**
No Action	4.46–10.0	3.71	3.71	3.71	3.41	3.32	3.04	**2.35**
Basic Coordination	16.0–31.11	3.04	**2.45**	**2.45**	**2.44**	**2.39**	**2.39**	**2.26**
Basic Coordination	14.0–16.0	3.32	2.93	2.93	**2.45**	**2.45**	**2.39**	**2.26**
Basic Coordination	12.0–14.0	3.71	3.17	3.04	2.93	**2.87**	**2.45**	**2.35**
Basic Coordination	10.0–12.0	3.71	3.41	3.32	3.17	3.04	**2.92**	**2.35**
Basic Coordination	4.46–10.0	3.71	3.71	3.56	3.32	3.17	3.06	**2.87**
Enhanced Coordination	16.0–31.11	2.93	**2.45**	**2.45**	**2.44**	**2.39**	**2.39**	**2.26**
Enhanced Coordination	14.0–16.0	3.17	**2.85**	**2.45**	**2.45**	**2.44**	**2.38**	**2.13**
Enhanced Coordination	12.0–14.0	3.25	2.93	**2.91**	**2.45**	**2.44**	**2.35**	**2.13**
Enhanced Coordination	10.0–12.0	3.32	3.17	2.93	**2.92**	**2.85**	**2.38**	**2.13**
Enhanced Coordination	4.46–10.0	3.71	3.32	3.17	3.06	2.93	**2.87**	**2.13**

Alternative	Flow Category (maf)	Max	90th percentile	75th percentile	Median	25th percentile	10th percentile	Min
Maximum Operational Flexibility	16.0–31.11	2.93	**2.45**	**2.45**	**2.44**	**2.39**	**2.39**	**2.26**
Maximum Operational Flexibility	14.0–16.0	3.17	**2.85**	**2.45**	**2.45**	**2.44**	**2.38**	**2.26**
Maximum Operational Flexibility	12.0–14.0	3.17	2.93	2.93	**2.85**	**2.45**	**2.38**	**2.27**
Maximum Operational Flexibility	10.0–12.0	3.17	3.17	2.93	2.93	**2.91**	**2.85**	**2.35**
Maximum Operational Flexibility	4.46–10.0	3.71	3.17	3.17	3.06	3.04	**2.92**	**2.35**
Supply Driven (LB Priority)	16.0–31.11	3.17	2.93	**2.45**	**2.45**	**2.44**	**2.39**	**2.26**
Supply Driven (LB Priority)	14.0–16.0	3.32	3.17	2.93	2.93	**2.45**	**2.44**	**2.26**
Supply Driven (LB Priority)	12.0–14.0	3.41	3.25	3.17	2.93	2.93	**2.85**	**2.35**
Supply Driven (LB Priority)	10.0–12.0	3.49	3.32	3.25	3.17	3.04	**2.92**	**2.38**
Supply Driven (LB Priority)	4.46–10.0	3.71	3.49	3.41	3.32	3.17	3.06	**2.87**
Supply Driven (LB Pro Rata)	16.0–31.11	3.17	2.93	**2.45**	**2.45**	**2.44**	**2.39**	**2.26**
Supply Driven (LB Pro Rata)	14.0–16.0	3.32	3.17	2.93	2.93	**2.45**	**2.44**	**2.26**
Supply Driven (LB Pro Rata)	12.0–14.0	3.41	3.25	3.17	2.93	2.93	**2.85**	**2.35**
Supply Driven (LB Pro Rata)	10.0–12.0	3.49	3.32	3.25	3.17	3.04	**2.92**	**2.38**
Supply Driven (LB Pro Rata)	4.46–10.0	3.71	3.49	3.41	3.32	3.17	3.06	**2.87**
Representative Preferred	16.0–31.11	2.93	**2.45**	**2.45**	**2.45**	**2.44**	**2.39**	**2.26**
Representative Preferred	14.0–16.0	3.17	2.93	**2.87**	**2.45**	**2.45**	**2.38**	**2.35**
Representative Preferred	12.0–14.0	3.32	3.17	2.93	2.93	**2.87**	**2.45**	**2.27**
Representative Preferred	10.0–12.0	3.41	3.17	3.17	3.17	2.93	**2.92**	**2.38**
Representative Preferred	4.46–10.0	3.71	3.41	3.32	3.25	3.17	3.04	**2.91**

Note: Ranks in bold are below the historically derived threshold of 2.93. This is the 90th percentile rank from 2008–2024 during LTEMP. Exceeding this value means that a larger percentage of potential resources are exposed to erosion risks than what has happened since Lake Powell was filled.

Table TA 12-5
Water Year Maximum Paleontological Preservation Risk at Lake Mead

Alternative	Flow Category (maf)	Max	90th percentile	75th percentile	Median	25th percentile	10th percentile	Min
CCS Comparative Baseline	16.0–31.11	2.54	2.38	2.33	**2.21**	**2.2**	**2.18**	**2.08**
CCS Comparative Baseline	14.0–16.0	2.75	2.52	2.39	2.33	**2.29**	**2.19**	**2.08**
CCS Comparative Baseline	12.0–14.0	2.75	2.54	2.52	2.39	2.33	**2.28**	**2.05**
CCS Comparative Baseline	10.0–12.0	2.75	2.75	2.54	2.52	2.38	**2.26**	**1.96**
CCS Comparative Baseline	4.46–10.0	2.75	2.75	2.54	2.4	**2.25**	**2.22**	**2.05**
No Action	16.0–31.11	2.59	2.54	2.4	**2.31**	**2.21**	**2.18**	**2.08**
No Action	14.0–16.0	2.75	2.59	2.54	2.41	2.33	**2.21**	**2.08**
No Action	12.0–14.0	2.75	2.59	2.59	2.54	2.38	**2.28**	**2.08**
No Action	10.0–12.0	2.75	2.75	2.59	2.54	2.38	**2.25**	**1.96**
No Action	4.46–10.0	2.75	2.75	2.59	2.39	**2.22**	**2.14**	**2.08**
Basic Coordination	16.0–31.11	2.59	2.38	2.33	**2.21**	**2.2**	**2.14**	**2.02**
Basic Coordination	14.0–16.0	2.59	2.52	2.38	**2.31**	**2.18**	**2.11**	**2.02**
Basic Coordination	12.0–14.0	2.75	2.54	2.4	2.35	**2.21**	**2.16**	**2.02**
Basic Coordination	10.0–12.0	2.75	2.75	2.54	2.38	**2.31**	**2.18**	**1.96**
Basic Coordination	4.46–10.0	2.75	2.75	2.52	2.39	**2.26**	**2.22**	**2.08**
Enhanced Coordination	16.0–31.11	2.54	2.33	**2.21**	**2.2**	**2.2**	**2.17**	**2.08**
Enhanced Coordination	14.0–16.0	2.59	2.35	2.33	**2.21**	**2.18**	**2.11**	**2.02**
Enhanced Coordination	12.0–14.0	2.75	2.39	2.35	2.33	**2.21**	**2.17**	**1.96**
Enhanced Coordination	10.0–12.0	2.75	2.54	2.52	2.36	2.33	**2.21**	**2.08**
Enhanced Coordination	4.46–10.0	2.75	2.59	2.52	2.4	2.33	**2.22**	**2.1**

Alternative	Flow Category (maf)	Max	90th percentile	75th percentile	Median	25th percentile	10th percentile	Min
Maximum Operational Flexibility	16.0–31.11	2.54	2.33	**2.21**	**2.2**	**2.2**	**2.18**	**2.1**
Maximum Operational Flexibility	14.0–16.0	2.59	2.38	2.33	**2.21**	**2.19**	**2.14**	**2.08**
Maximum Operational Flexibility	12.0–14.0	2.59	2.42	2.38	**2.28**	**2.19**	**2.11**	**2.02**
Maximum Operational Flexibility	10.0–12.0	2.75	2.54	2.42	2.36	**2.21**	**2.14**	**2.02**
Maximum Operational Flexibility	4.46–10.0	2.75	2.59	2.52	2.39	2.33	**2.19**	**2.08**
Supply Driven (LB Priority)	16.0–31.11	2.59	2.33	**2.21**	**2.2**	**2.2**	**2.2**	**2.11**
Supply Driven (LB Priority)	14.0–16.0	2.59	2.38	**2.32**	**2.2**	**2.19**	**2.14**	**2.08**
Supply Driven (LB Priority)	12.0–14.0	2.75	2.42	2.35	**2.21**	**2.18**	**2.11**	**2.02**
Supply Driven (LB Priority)	10.0–12.0	2.75	2.59	2.52	2.33	**2.18**	**2.11**	**1.96**
Supply Driven (LB Priority)	4.46–10.0	2.75	2.75	2.52	2.39	**2.25**	**2.17**	**1.96**
Supply Driven (LB Pro Rata)	16.0–31.11	2.59	2.33	**2.21**	**2.2**	**2.2**	**2.2**	**2.11**
Supply Driven (LB Pro Rata)	14.0–16.0	2.59	2.38	**2.32**	**2.2**	**2.19**	**2.14**	**2.08**
Supply Driven (LB Pro Rata)	12.0–14.0	2.75	2.42	2.35	**2.21**	**2.18**	**2.11**	**2.02**
Supply Driven (LB Pro Rata)	10.0–12.0	2.75	2.59	2.52	2.33	**2.18**	**2.11**	**1.96**
Supply Driven (LB Pro Rata)	4.46–10.0	2.75	2.75	2.52	2.39	**2.25**	**2.17**	**1.96**
Representative Preferred	16.0–31.11	2.54	2.35	**2.21**	**2.2**	**2.2**	**2.18**	**2.02**
Representative Preferred	14.0–16.0	2.59	2.38	2.33	**2.21**	**2.18**	**2.11**	**2.02**
Representative Preferred	12.0–14.0	2.59	2.52	2.38	**2.32**	**2.18**	**2.11**	**2.02**
Representative Preferred	10.0–12.0	2.75	2.54	2.52	2.38	**2.32**	**2.17**	**1.96**
Representative Preferred	4.46–10.0	2.75	2.59	2.54	2.52	2.35	**2.25**	**1.96**

Note: Ranks in bold are below the historically derived threshold of 2.33. This is the 90th percentile rank from 2008–2024 during LTEMP. Exceeding this value means that a larger percentage of potential resources are exposed to erosion risks than what has happened since Lake Mead was filled.

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Technical Appendix 13

Tribal Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
CAP	Central Arizona Project
CCS	Continued Current Strategies
Final EIS	Final Environmental Impact Statement
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
NRHP	National Register of Historic Places
Reclamation	Bureau of Reclamation
SIB	Southerly International Boundary
TCP	traditional cultural place

TA 13. Tribal Resources

The Colorado River, its canyons, and its associated ecosystems figure prominently in the cultural traditions of many tribal communities. For these tribes, the river and canyons are living entities consisting of sacred spaces, the homes of their ancestors, the residence of the spirits of their dead, and the source of culturally important resources. Indigenous worldviews do not separate cultural and natural environments, as Western science often does; instead, they view all resources—whether considered cultural or natural in Western frameworks—as interconnected and interdependent. Many tribes see themselves as stewards of the Colorado River and its canyons, which are a vital part of the living and spiritual world; caring for the river and the canyons is their responsibility.

Tribal resources can include archaeological resources, structures, topographic features, habitats, plants, wildlife, and minerals that Indigenous peoples, tribes, or other groups consider essential for the preservation of traditional culture and traditional values. For many tribes, the trails used to access the river are also considered culturally important landscape features. Tribal interests also include values and resources reflected in other sections of this Final Environmental Impact Statement (Final EIS), including water for drinking water and agriculture, recreational resources, and many other socioeconomic and environmental aspects that overlap other sections. These resources are not just those that are essential for the preservation of traditional culture and values but for contemporary use and exercise of tribal sovereignty.

Traditional values of living communities can be manifested at locations called traditional cultural places (TCPs), Indian sacred sites, or cultural landscapes. The Colorado River and its canyons are considered by many tribes to be a TCP. As described by National Park Service guidance on TCPs (NPS 2024:7), a TCP is "a building, structure, object, site, or district that may be listed or eligible for listing in the National Register for its significance to a living community because of its association with cultural beliefs, customs, or practices that are rooted in the community's history and that are important in maintaining the community's cultural identity." Of the groups concerned, the Hualapai Tribe (Coulam 2011), Hopi Tribe (Hopi CPO 2001), Navajo Nation (Maldonado 2011), and Pueblo of Zuni (Dongoske 2011) have prepared National Register of Historic Places (NRHP) nomination forms for the Colorado River and its canyons as a TCP. The Bureau of Reclamation (Reclamation) is actively consulting with tribes regarding the Colorado River and its canyons, including associated Traditional Ecological Knowledge, that will be incorporated as it becomes available.

TA 13.1 Affected Environment

The study area for tribal resources is identical to that discussed in **TA 11**, Cultural Resources, and **TA 18**, Indian Trust Assets. It extends from the northern extent of Lake Powell to the Southerly International Boundary (SIB) and consists of the Colorado River channel from bank to bank except from Glen Canyon Dam to Lake Mead, where it stretches from canyon rim to canyon rim, as well as a 0.5-mile buffer on either side of the riverbank or canyon rim. The study area coincides with the

search area used for a Class I records search conducted for this Final EIS document (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi et al. 2024).

Fourteen Native American tribes consider portions of the study area to be part of their homelands. Of these, eight tribes—A:shiwi (Zuni), Ndee (Western Apache), Diné (Navajo), Havasupai, Hualapai, Hopi, Nüümü (Southern Paiute), and Yavapai—are associated directly with the Grand Canyon. Five tribes—Cocopah, Pipa Aha Macav (Mojave), Piipaash (Maricopa), Quechan, and Xalchidom (Halchidhoma)—have homelands along the lower Colorado River where it flows south to the Gulf of California, and one group, the Núuchi (Ute), used northeastern portions of the river and study area. Contemporary Native American communities face a host of common issues, such as widespread poverty, health disparities, and housing shortages. For the Native American tribes discussed here, water shortages and the potential impact on agricultural endeavors are a significant concern. The brief summaries provided below focus on Indigenous cultural connections to the Colorado River landscape and are derived primarily from the multivolume Class I cultural resources literature review conducted in support of this analysis (Tremblay et al. 2024a, 2024b; Eddy et al. 2024; Winslow et al. 2024; Eskenazi et al. 2024).

TA 13.1.1 A:shiwi (Zuni)

The Zuni (A:shiwi) origin story recounts that the People emerged from the fourth underworld via a hole at *Chimik'yana'kya dey'a*, (Ribbon Falls) on a tributary drainage of Bright Angel Creek which flows south from the North Rim of the Grand Canyon into the Colorado River. From the Grand Canyon, groups spread in four directions, leaving behind glyphic symbols on rocks and structural signs that the Zuni recognize today. Some continued to Chavez Pass, others into Mexico, the San Francisco Peaks, the present-day Bandelier National Monument in the Fremont archaeological area, and ultimately to *Halona:wa* "Anthill" where they created Zuni Pueblo, *A:shiwi,* at the central or Middle place. Zuni religion is focused on water, and the waters of the Colorado River are described as sacred. Even dry washes are important—Zuni deem them "passageways" for water, whether water flows there year-round or not. Long before Europeans first saw and named the Colorado River, the Zuni named this watercourse *K'yawan' A:honanne.*

The lands through which the Zuni migrated were never abandoned; their ancestors still inhabit the land. Each ancestral site is incorporated into a broad cultural landscape that encapsulates the Zuni pilgrimage experience and the lessons learned therefrom. The Zuni have provided the following account regarding the Zuni cultural landscape within the study area considered in this document:

> To *A:shiwi*, Chaco Canyon is known as *Heshoda Bitsulliya/Ki:whihtsi Bitsulliya* and in the name *K'yakwe: A:mossi*, or "House of Puebloan High Priests." The greater *A:shiwi* Chaco traditional cultural land/waterscape is simultaneously a dynamic and diverse and inter-functional and unified geographical area densely lined and dotted with multiple intensive zones of historical significance and ongoing traditional religious and cultural importance. The interconnected and interrelated layers and dimensions of multiple intensive middle zones of the district both circularly and circuitously pivot—in space and time—on *Heshoda Bitsulliya/Ki:whihtsi Bitsulliya*, Chaco Canyon, while always connecting and radiating to and from the spatial anchors of *Idiwana'a*, the Zuni Pueblo, and *Chimik´yana´kya dey´a* and *Kuhnin A´l´akk´wa*, the Grand Canyon. The connective umbilical tissues and relations of *Heshoda Bitsulliya/Ki:whihtsi*

> *Bitsulliya* are vast for *A:shiwi* and can be topographically diagrammed and understood to extend at least from *Kuhnin A´l´akk´wa*, Grand Canyon, in Arizona to the west to *Shiba:bulim´a*, Bandelier National Monument, in New Mexico to the east. The historic district's northern reach extends at a minimum to the areas of Abajo (Blue) Mountains and Montezuma Canyon in southeast Utah and Alkali Canyon in southwest Colorado, and its southern reach to the area of *K'yak'yali an Yalanne*, or Eagle Peak, in the central western region of New Mexico. Each of these intensive center or middle spatial zones that help diagram the outlines of the greater *A:shiwi* Chaco traditional cultural land/waterscape and historic district connect and convey three delineable "time periods" that are simultaneously layered and intersecting in their discernability (Curti et al. 2023: Executive Summary).

Thus, the Zuni have a deep and personal interest in the Colorado River and its tributaries since their emergence in this world. In addition to the emergence place, Chimik'yana'kya dey'a, (Ribbon Falls) on Bright Angel Creek, K'yawan' A:honanne (Colorado River), and Ku'nin A'l'akkwe'a (Grand Canyon) are considered to be Zuni TCPs. The Zuni also recognize Gold Strike Canyon-Sugarloaf Mountain near Boulder City, Nevada, as an important ceremonial location that has been listed on the NRHP as a TCP. The Colorado River is important to modern tribal communities as the Zuni continue to make pilgrimages to the Grand Canyon for religious purposes and to gather willow, herbs, sands, clays, and minerals including salt and pigments.

TA 13.1.2 Cocopah

The Cocopah are the southernmost Yuman Tribe along the lower Colorado River, living on both sides of the river from its delta to the Yuma area. They often aligned with Piipaash and Xalchidom, against the Quechan—their nearest neighbor to the north along the river. Cocopah creation stories tell of twin gods who began under the waters of the lower Colorado River and emerged to form the earth and its creations. The Ripley Intaglios near Blythe, California have been listed on the NRHP as a TCP.

TA 13.1.3 Diné (Navajo)

The Navajo Nation (Diné) views the Colorado River and the Grand Canyon as sacred, with the river considered a living being. Spanning from the Animas River to the Pacific Ocean, this landscape holds significant cultural and ceremonial importance, with the Colorado and Little Colorado Rivers playing key roles in Navajo practices. They perform prayers and rituals to honor these waters, which are integral to their spiritual practices and subsistence. Deities are believed to reside in the river canyons, and various ceremonies are associated with the Colorado River, highlighting the importance of preserving these resources and the Navajo's sovereignty.

Historical trails, such as the Salt Trail, Lees Ferry, and the Havasupai Trail, were used for hunting, gathering, and trading. The Salt Trail is particularly culturally significant due to Salt Woman's journey and offerings at a sacred rock. The Grand Canyon also provided refuge during conflicts, and the junction of the Colorado and Little Colorado Rivers is a sacred place in Diné culture.

The Diné people's activities and settlements in the Grand Canyon include cornfields, grazing areas, livestock corrals, former homesites, sweathouses, and ceremonial hunting landscapes. Numerous locations important to Navajo history and culture exist within the Grand Canyon. Significant sites

along the river corridor include Big Sand Dune, hogans at Lees Ferry, and beaches formerly used as cornfields.

Navajo traditions underscore the profound connection between the Navajo people and their land, illustrating how their cultural heritage is deeply intertwined with the natural landscape. The Navajo have nominated several locations along the Colorado and Little Colorado Rivers at TCPs to the NRHP. Additionally, ethnohistoric research conducted during the 1990s identified many locations and resources that would likely qualify.

TA 13.1.4 Havasupai

The Havasupai Tribe, also known as *Havasu 'Baaja* (People of the Blue Green Water), are from the region near Havasu Falls at the bottom of the Grand Canyon and are sometimes referred to as the guardians of the Grand Canyon. The Havasupai's historical territory extended from the southern bank of the Colorado River to the San Francisco Peaks, east to the Little Colorado River, and west to the Hualapai reservation. The San Francisco Peaks are central to Havasupai cosmology. In 1975, their reservation was expanded to include the Havasupai Traditional Use Lands, an area within Grand Canyon National Park acknowledged to be important to the Havasupai people. The Havasupai were regarded by the Hopis as guardians of the Grand Canyon and its sacred sites.

Water holds immense cultural and religious significance, with sacred springs and the Colorado River being integral to the tribe's worldview. All springs are considered sacred, and offerings are made before using the water. Spirits are believed to inhabit various geographic locations in and around the Colorado River corridor, including Gray Mountain, the Great Thumb peninsula, the San Francisco Peaks, and Mount Sinyella. These sites play a significant role in their spiritual practices, particularly rain-making rituals. No TCPs associated with Havasupai cultural places have been formally documented.

TA 13.1.5 Hopi

The Hopi Tribe consists of clans from the Four Corners region, the Southwest, Mexico, and possibly South America. They speak the Uto-Aztecan language of Hopi. The ancestral Hopi, known as the *Hisatsinom*, migrated extensively across the southwestern United States before settling at the Hopi Mesas. During their travels, many resided in the canyons. The Hopi people believe they emerged into the present world from the *Sipapuni*, a spring located in the Little Colorado River gorge near its confluence with the Colorado River. The Hopi Tribe's presence in the Grand Canyon region spans over 1,000 years, with archaeological evidence dating their use of the canyons to at least AD 700–800. By AD 1000, numerous small pueblo sites were established. These sites, which include kivas and shrines, are of profound religious and cultural importance. The Hopi consider these sites to be active and sacred, with a spiritual responsibility to protect them.

Currently, the Hopi live in pueblos on and below the Hopi Mesas, growing crops like corn, beans, squash, and peaches. Water is central to their ceremonies, symbolizing the most precious resource, the source of all life, and their connection to ancestors. TCPs identified by the Hopi include *Öngtupqa* (Grand Canyon), *Palavayu* (Little Colorado River), and *Pisisvayu* (Colorado River). Additional locales include the Hopi origin location *Sipapuni*; Hopi Salt Mine *Öönga*; Lees Ferry; archaeological sites and shrines along the Colorado River within the Grand Canyon, with the canyon

rim as the boundary beginning at the Colorado River confluence with Kanab Creek on the west, downstream of Glen Canyon Dam on the east, and up Little Colorado River Gorge to the Cameron area.

TA 13.1.6 Hualapai

The Hualapai, also known as *Hwal 'baia*, are an upland Yuman people related to the Havasupai Tribe. Their reservation is adjacent to the south bank of the Colorado River and the Grand Canyon. The tribe consists of 12 bands, each named after significant topographical features within their land. The Grand Canyon and Colorado River, from the Little Colorado River to the Bill Williams River confluence, are significant to the Hualapai. Additionally, the Hualapai have a rich origin story that begins at Spirit Mountain and includes the Grand Canyon.

Historically, the Hualapai were hunter-gatherers and agriculturalists, moving seasonally and cultivating crops like corn, beans, and squash. They were skilled hunters and traded with neighbors; they have historically engaged in trade, social interactions, and conflicts with neighboring tribes and European Americans. The Hualapai regard all archaeological and cultural resources within their traditional territory as sacred TCPs. These include plants, wildlife, rock writings, artifacts, and traditional use areas. The Hualapai have nominated several locations along the Colorado River for listing on the NRHP as TCPs.

TA 13.1.7 Ndee (Western Apache)

At the time of contact with Spanish and Euro-American people, the Ndee occupied much of central and northern Arizona and were loosely organized in three to five subtribes based on family lineages and slight differences in language. Oral histories tell of a place located north of the Little Colorado River where the Ndee lived near the Navajo and Hopi. This place is called place "camp beneath the water," "camp beside the water," or "dance camp." Many Ndee bands state that it is a place of emergence from beneath the earth's surface into this world. From this place, bands crossed the Little Colorado River and split into different areas of central Arizona, below the Mogollon Rim. Ndee bands roamed broadly across this region, including the Grand Canyon. The area surrounding the Grand Canyon provided pinyon nuts, sumac berries, and medicinal herbs, as well as hunting grounds for antelope and deer.

The Ndee refer to the Grand Canyon as *Che Da* or *Ge Da Cho*, which roughly translate to the "Rock Cliff" or the "Big Edge." The Colorado River is *Tule'chee*—"Red River"—describing the color of the water in its natural state. Ndee stories recount the creation of the Grand Canyon by a deity named *Naa Ye' Nas Ghane'*. Because of this association with a deity, the canyon is considered a sacred place. Although Western Apache use of the Grand Canyon and Colorado River are well documented by tribal oral tradition, they have not formally identified any TCPs to date.

TA 13.1.8 Núuchi (Ute)

Ute are the easternmost of the Numic-speaking peoples thought to have migrated from southeastern California/southern Nevada in a northeastern arc across the Great Basin. The Núuchi occupied what is now eastern Utah and western/central Colorado. Núuchi gathered roots (wild onion, Indian potato), seeds that were eaten raw or ground into meal, chokecherry and berries, the interior bark of ponderosa pine, prickly pear, and other plants for medicines and tools. They hunted game such as

rabbits, elk, and deer, and traded with Puebloans and later, the Spanish for horses, cattle, and sheep. Ute use of the Colorado River is not well documented, nor have they identified any TCPs to date.

TA 13.1.9 Nüümü (Southern Paiute)

The Southern Paiute inhabited the Colorado River Basin in northwestern Arizona, southern Nevada, and the north and west bank of the Colorado River. Their traditional territory extended north and west of the Colorado River. The nation was divided into the western *Paranayi* and the eastern *Yanawant*, each with different bands. Individuals with knowledge of water sources were highly regarded, and there was a belief in supernatural beings called Water Babies associated with springs and underground water. They practiced small-scale agriculture, gathered wild resources, and believed in supernatural forces, particularly near Charleston Peak in the Spring Mountains.

They have a strong cultural and spiritual connection to the land and its resources, especially the Colorado River (*Piapaxa*). The Southern Paiute Tribes have a profound cultural connection to the Colorado River, viewing it as a powerful natural resource that must be respected and preserved. Paiute elders documented important cultural practices and locations within the Grand Canyon and Colorado River, including the sacredness of agave roasting sites, the use of red pigment for protection and rituals, and the inherent power of rocks and burials. Artifacts are believed to belong to their original owners and should remain undisturbed.

The San Juan Paiutes used specific crossing locations on the Colorado River, and the Kaibab Paiute had trails leading to their winter camps. The Southern Paiute Chemehuevi Salt Song Trail traveled from southern Nevada through the Mojave valley to the lower Colorado River valley. The Southern Paiute have declared the entire Colorado River region a TCP due to its cultural significance. Additionally, the Southern Paiute have identified Gold Strike Canyon-Sugarloaf Mountain, which is a ceremonial location near Boulder City, Nevada, as a TCP.

TA 13.1.10 Piipaash (Maricopa) and Xalchidom (Halchidhoma)

The Piipaash and Xalchidom are Yuman-language speakers who migrated from the lower Colorado River area and ultimately joined the Akimel O'odham on the Salt and Gila ivers near Phoenix. The Piipaash were located along the Lower Gila River when they encountered the Spanish in the late 1600s but likely had previously resided on the lower Colorado River. The Xalchidom occupied both sides of the lower Colorado River south of the Aha Macav and north of the Quechan; they may have been farther south on the river in earlier times, but they were pressured by their neighbors and frequently relocated their villages. Once they were driven from the Colorado River, their former territory was occupied by the Chemehuevi. Due to pressure from the Aha Macav and Quechan, both groups emigrated eastward up the Gila River, and by 1830, joined the Akimel O'odham. They were supported by the O'odham in a final victorious battle against the Quechan/Aha Macav at Pima Butte in 1857. Specific TCPs along the lower Colorado River have not been reported for either tribe. Piipaash and Xalchidom origin stories are similar to that of the Ahi Macav and they, too, consider Avi Kwa Ame to be their sacred origin place.

TA 13.1.11 Pipa Aha Macav (Mojave)

The Pipa Aha Macav (people by the river) are the northernmost Yuman Tribe. Their tribal territory is found along both sides of the Colorado River in the Mojave Valley, and at times, in portions of

the Mojave Desert to the northwest. Traditionally the Pipa Aha Macav lived in earth-covered houses in large seasonal settlements on the terraces above the Colorado River floodplain during the winter and spring. Once waters had receded, extended families established camps with small brush shelters near their crops on the floodplain where they dry-farmed corn, pumpkin, tepary beans, gourds, cotton, and sunflowers. They were renowned traders, carrying goods between the Pacific Ocean and the Pueblos via the Mojave Trail westward from the river through the western Mojave Desert, and eastward via the Moqui Trail through the Grand Canyon to the Hopi, trading with tribes along the way. Tribal origins center on Avi Kwa Ame (Spirit Mountain), which was designated a National Monument in March 2023, and oral tradition tells of *Mutavilya* who is said to have created the Colorado River, its plants and animals, and instructed the Pipa Aha Macav in the arts of civilization.

The Colorado River and Avi Kwa Ame are sacred places to all Yuman Tribes, including the Pipa Aha Macav. Indeed, the Colorado River Indian Tribes have enacted a Tribal Resolution under Tribal law that states, in part, "the Colorado River is a living being carrying and sustaining life as it flows through the reservation and our ancestral lands." This statement reflects the basic core values of the Colorado River Indian Tribes, including the cultural, spiritual, and religious connection between the Colorado River and the welfare of the Colorado River Indian Tribes and its members. Other locations considered sacred include springs, caves, sleeping circles, trails along the river that were traveled via dreams or by walking them, offerings placed among rock cairns along trails, large geoglyphs created on the surface of the desert by removing stones from areas of desert pavement or by placing stones atop areas lacking desert pavement (e.g., the Ripley Intaglios), and pictographs and petroglyphs. Many of these features have yet to be publicly identified by tribal members or formally recorded.

TA 13.1.12 Quechan

The Quechan originally lived near the river delta at the Gulf of California, later moving to the Gila and Colorado Rivers junction and expanding into the Palo Verde Valley. Their creation story, similar to the Pipa Aha Macav, involves the god *Kukumat* creating the Quechan and other tribes on the sacred mountain *Avikwame'*. After *Kukumat's* death, his body and house were burned. *Kumastamxo*, the divine son of the creator, is a central figure, credited with creating the keruk ceremony to commemorate *Kukumat's* death. The Colorado River region is vital to their cultural and ethnic identity, with various landmarks and natural features holding spiritual significance.

In addition to Avi Kwa Ame, other TCPs associated with the river include the trail taken by the Quechan from Avi Kwa Ame south toward the delta; it is called the *xam kwatcám* ("another going down") and is the inspiration for the tribal name. It is the major north–south trail along the west bank of the lower Colorado River and leads to Pilot Knob, another sacred landform, near the Gulf of California. The trail has also been identified as the Keruk Trail, which is the path taken by the dead as part of the cremation ceremony. As with the Pipa Aha Macav, many legendary figures are commemorated within Quechan territory as large geoglyphs on terraces along the banks of the lower Colorado River; smaller geoglyphs are located farther inland on either side of the river.

TA 13.1.13 Yavapai

The Yavapai people traditionally inhabited the area north of the Gila River, between the Colorado and Verde Rivers. They belong to the Pai branch of the Yuman language family and are divided into

four subgroups: western Apache or Tolkapaya, northwestern Wipukpaya, northeastern Yavapai or Apache-Mojaves, and southeastern Yavapai or Kewevkapaya. The Yavapai intermarried with the Tonto Apaches and have various origin theories, including connections to Hakatayan patterns, Sinagua peoples, or a Yuman migration. They first encountered the Spanish in the Verde River Valley in the early 1580s.

Before their removal to reservations in the late 19th century, they lived west of the Verde River. Their origin story includes sacred sites such as San Francisco Peak and Montezuma's Well. Yavapai families traveled in bands, hunting and gathering seasonally available foods. They hunted deer, jackrabbits, rabbits, quail, and woodrats, and planted crops like corn, squash, and beans, which they harvested in the fall. The western Yavapai traded animal skins, baskets, and agave for agricultural products from the Pipa Aha Macav and Quechan. There are no specific Yavapai TCPs recorded within the Grand Canyon or Colorado River, but their use of the canyon is similar to that of the Western Apache.

TA 13.1.14 Ethnographic Resources and Traditional Cultural Places

Several known or documented TCPs within or adjacent to the study area have been listed or are eligible for listing in the NRHP (**Table TA 13-1**). One each is recorded for the A:shiwi and Hopi within Grand Canyon; Sugarloaf Mountain to the west of the lower Colorado River is identified as a TCP by the A:shiwi, Diné, Hopi, Hualapai, Nuwuvi, Pipa Aha Macav, and Yavapai; and the Ripley Intaglios are considered sacred by all Yuman Tribes. The Yuman Tribes consider their origin place, Avi Kwa Ame (Spirit Mountain), to be sacred; it is beyond the project study area but within the newly created Avi Kwa Ame National Monument.

Through ongoing consultation with tribes, the locations of several additional places that are considered sacred have been disclosed to Reclamation cultural resources staff. At the request of these tribes, descriptions and locations of those sacred places are confidential. Tribes discussed in this section revere the Colorado River. The Grand Canyon itself is an NRHP-eligible TCP for multiple tribes. Plants and animals, among other entities, are considered contributing elements to the TCP. Some, like aquatic beings, are considered significant elements unto themselves, often representing the ancestors of the living people. Several important locations within the Grand Canyon TCP have been formally recorded in the canyon for the A:shiwi and Hopi and documented in ethnographic studies for the Diné and Hualapai.

Tribes consider places associated with origin stories, migrations, songs, and ceremonies to be sacred TCPs, as well as ancestral sites, trails, cairns, and rock writing/petroglyphs/pictographs/geoglyphs. All water sources, especially those that come from below ground, are sacred. Plants, animals, and minerals are considered traditional cultural resources, often associated with specific locations. Reclamation is in ongoing consultation with tribes to identify specific locations/resources important to each tribe.

Table TA 13-1
NRHP-Listed or Eligible TCPs

Tribe	TCP Description
A:shiwi (Zuni)	*Chimik'yana'kya dev'a* (Place of Emergence), Ribbon Falls on Bright Angel Creek, *K'yawan' A:honanne* (Colorado River), and *Ku'nin A'l'akkwe'a* (Grand Canyon) Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location near Boulder City, Nevada
Hopi	*Öngtupqa* (Grand Canyon), *Palavayu* (Little Colorado River), and *Pisisvayu* (Colorado River). Additional locales include the origin location *Sipapuni* (NA 10536 MNA*); Hopi Salt Mine *Öönga* (NA 10537/AZ C:13:3[GCNP]);** Lees Ferry; archaeological sites and shrines, with the canyon rim as the boundary beginning at the Colorado River confluence with Kanab Creek on the west, downstream of Glen Canyon Dam on the east, and up Little Colorado River Gorge to the Cameron area Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location near Boulder City, Nevada
Diné (Navajo)	None formally recorded within Grand Canyon; ethnohistoric research in the 1990s identified many locations and resources that would likely qualify Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location near Boulder City, Nevada
Ndee (Western Apache)	None formally recorded
Núuchi (Ute)	None formally recorded
Nüümü (Southern Paiute)	Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location near Boulder City, Nevada
Havasupai (Yuman – Pai Branch)	None formally recorded
Hualapai (Yuman – Pai Branch)	None formally recorded in Grand Canyon; archaeological and botanical surveys in 1990s identified traditional use areas, sacred places, and traditional resources of concern that would likely qualify Listed 2004: Gold Strike Canyon-Sugarloaf Mountain (near Boulder City, Nevada) as a ceremonial destination
Yavapai (Yuman – Pai Branch)	Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location near Boulder City, Nevada
Cocopah, Piipaash, Pipa Aha Macav, Quechan, Xalchidom (Yuman – River Branch)	Listed 1975: Ripley Intaglios Listed 2004: Gold Strike Canyon-Sugarloaf Mountain, a ceremonial location (claimed by Pipa Aha Macav)
Fort Mojave Indian Tribe of Arizona, California, and Nevada	Determined eligible 2018: Amut Ahar TCP

* MNA = Museum of Northern Arizona, incorporated into the state-assigned site number
** GCNP = Grand Canyon National Park, incorporated into the state-assigned site number issued by the Arizona State Museum for the Hopi Salt Mine located on National Park Service-managed lands within the national park

TA 13.2 Environmental Consequences

TA 13.2.1 Methodology

Of primary concern is how the alternatives affect the integrity and sacredness of tribal resources. Because these resources attain significance through tribal cultural customs, and because many of these resources are sacred and their locations confidential, the tribes are best situated to understand how the alternatives might affect them. Accordingly, the impact analysis is primarily qualitative and informed by ongoing tribal consultation.

There are many federally recognized tribes with entitlements to Colorado River water or who may be affected or have interests in the proposed federal action. There are 30 federally recognized tribes within the geographic Basin. Reclamation consults regularly with these tribes regarding Colorado River issues. Additionally, the Ten Tribes Partnership is a coalition of 10 federally recognized tribes with rights and unresolved claims to Colorado River water. The partnership was created in 1992 and has an ongoing consultation relationship with Reclamation. Of the 22 federally recognized tribes in Arizona, 4 have quantified water rights, or partially quantified rights to water from the mainstream Colorado River through the Consolidated Decree. Another 10 tribes in Arizona have entered water rights settlements that include Central Arizona Project (CAP) water, one source of which is Priority 4 Arizona Colorado River water. Several more tribes hold CAP contracts.

Reclamation has a long-standing and ongoing consultation relationship with CAP Tribes. Reclamation consults not only with tribes who hold water rights or are located within the Basin's geographic boundary but also with a total of 43 tribes who may be affected or have interests in actions on the Colorado River (**Table TA 13-2**). Consultation and coordination with these tribes are ongoing.

Table TA 13-2
Tribes Invited to Consult on Colorado River Issues

• Ak-Chin Indian Community of the Maricopa Indian Reservation	• Pueblo of Pojoaque
• Chemehuevi Indian Tribe of the Chemehuevi Reservation	• Pueblo of San Felipe
• Cocopah Tribe of Arizona	• Pueblo of San Juan
• Colorado River Indian Tribes of the Colorado River Indian Reservation	• Pueblo of Sandia
• Fort McDowell Yavapai Nation	• Pueblo of Santa Ana
• Fort Mojave Indian Tribe of Arizona, California, and Nevada	• Pueblo of Santa Clara
• Gila River Indian Community	• Pueblo of Tesuque
• Havasupai Indian Tribe of the Havasupai Reservation	• Pueblo of Zia
• Hopi Tribe of Arizona	• Quechan Tribe of the Fort Yuma Indian Reservation

• Hualapai Indian Tribe of the Hualapai Indian Reservation	• Salt River Pima-Maricopa Indian Community of the Salt River Reservation
• Jicarilla Apache Nation	• San Carlos Apache Tribe of the San Carlos Reservation
• Kaibab Band of Paiute Indians of the Kaibab Indian Reservation	• San Juan Southern Paiute Tribe of Arizona
• Las Vegas Tribe of Paiute Indians of the Las Vegas Indian Colony	• Southern Ute Indian Tribe of the Southern Ute Reservation
• Moapa Band of Paiute Indians of the Moapa River Indian Reservation	• Tohono O'odham Nation of Arizona
• Navajo Nation	• Tonto Apache Tribe of Arizona
• Paiute Indian Tribe of Utah	• Ute Indian Tribe of the Uintah and Ouray Reservation
• Pascua Yaqui Tribe of Arizona	• Ute Mountain Tribe of the Ute Mountain Reservation
• Pueblo of Acoma	• White Mountain Apache Tribe of the Fort Apache Reservation
• Pueblo of Cochiti	• Yavapai-Apache Nation of the Camp Verde Indian Reservation
• Pueblo of Jemez	• Yavapai-Prescott Tribe of the Yavapai Reservation
• Pueblo of Laguna	• Zuni Tribe of the Zuni Reservation
• Pueblo of Nambe	

Impact Analysis Area

The study area for tribal resources is identical to that discussed in **TA 11**, Cultural Resources. It includes the Colorado River corridor from the upper limits of Lake Powell in Utah, through the Grand Canyon in Arizona and Lake Mead in Arizona, and from Hoover Dam to the SIB.

Assumptions

Assumptions for the following analysis are:

- Information regarding specific tribal resources and potential impacts on those resources will be provided by the tribes during consultation.

Impact Indicators

Impact indicators for this analysis are:

- Qualitative assessment of potential impacts on TCPs informed by tribal consultation.
- Qualitative assessment of potential impacts on culturally important resources informed by tribal consultation and by reference to relevant quantitative analysis sections of this Final EIS (e.g., **TA 9**, Vegetation Including Special Status Species, **TA 8**, Biological Resources – Fish and Other Aquatic Resources, etc.)

TA 13.2.2 Issue 1: How will any changes in dam operations affect TCPs?

TCPs are historic properties that are eligible for listing on the NRHP principally for their association with culturally significant events as told through Indigenous oral history or with individuals named by those traditions. Impacts on TCPs would consist primarily of changes to the natural environmental context resulting from continued active management of reservoir levels and water releases to downstream river segments. Impacts could also occur as reservoir elevations change and expose TCPs to increased visitation. Because TCPs are a specific category of historic property, adverse impacts on TCPs would be addressed through the project's programmatic agreement developed in compliance with Section 106 of the National Historic Preservation Act or through ongoing consultation with affected tribes.

Exposure of TCPs as lake levels fluctuate as a result of management actions described by the alternatives would facilitate access to these culturally important locations by tribal members but would also increase access for non-Native visitation. End of year lake elevations for each alternative are explored in detail in **TA 3**, Hydrologic Resources, and are summarized here in discussion of impacts on TCPs.

Across all alternatives and the Continued Current Strategies (CCS) Comparative Baseline, Lake Powell's median water year elevations are generally similar under wet hydrologic conditions, except for the Supply Driven Alternative (both Lower Basin [LB] Priority and LB Pro Rata approaches), which show lower median elevations. As conditions become drier, Lake Powell's elevations decrease and differences among alternatives become more pronounced, with operations varying widely at lower water levels.

In the two driest flow categories, the Enhanced Coordination Alternative maintains the highest median reservoir elevations, followed by the Maximum Operational Flexibility Alternative. Both of these alternatives keep median reservoir elevations well above the critical threshold of 3,500 feet, even during dry periods exposing the fewest number of TCPs to increased visitation. In contrast, the No Action Alternative and the Basic Coordination Alternative have median elevations that fall below this critical threshold in dry conditions, and these alternatives would facilitate greatest access to TCPs. Under the Representative Preferred Alternative, Lake Powell elevations remain relatively stable compared to other alternatives. In both the Dry Flow and Critically Dry Flow Categories the Representative Preferred Alternative maintains median elevation above 3,500 feet. The Critically Dry Flow Category shows greater variability in median elevations.

For Lake Mead, median calendar year elevations also decline as conditions become drier, but the relative performance of each alternative remains consistent. The Supply Driven Alternative (LB Pro Rata approach) consistently has the highest median reservoir elevations across all flow categories, followed by the LB Priority approach exposing the fewest number of TCPs to increased visitation. The No Action Alternative consistently has the lowest median elevations, with the CCS Comparative Baseline having the second lowest and these alternatives would facilitate greatest access to TCPs. Most action alternatives show wide variability in Lake Mead's elevations, except for the Maximum Operational Flexibility Alternative, which reliably remains above 975 feet. Under the Representative Preferred Alternative, Lake Mead elevations show moderate variability in dry

conditions and somewhat lower variability in critically dry conditions staying above 975 feet in most years.

TA 13.2.3 Issue 2: How will any changes in dam operations affect lake elevations and river flows downstream which may impact archaeological sites sacred sites?

Sacred sites are specific locations that have been identified by a tribe as sacred because of its traditional religious significance or as a discrete location for ceremonial use. Sacred sites often overlap significantly with TCPs and with Indigenous archaeological sites. Accordingly, impacts on sacred sites are qualitatively similar to impacts on archaeological sites. Here, of primary concern are direct impacts like wave action and wet-dry cycling that could occur from changes in lake levels or from changes to river flows caused by annual releases. Impacts on archaeological sites are analyzed in detail in **TA 11**, Cultural Resources, and that discussion is summarized here.

At Lake Powell and Lake Mead, continuous inundation of sacred sites or Indigenous archaeological sites helps preserve them better than cycles of flooding and exposure, which increase risks from wave action. The main concern is that dropping lake elevations could expose such sites that were previously underwater, making them vulnerable to wet-dry cycles and wave impacts. As water levels fall, more sites become exposed to these risks at lower elevations. Sites at higher elevations may be less affected by wet-dry cycling and wave action but could become more accessible depending on their location.

Hydrological models show that during wet conditions, Lake Powell's water levels are projected to remain above 3,660 feet in all scenarios. As conditions get drier, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain the highest median water levels during the Average Flow Category, staying at or above 3,620 feet. These alternatives also perform best in the Critically Dry Flow Category, but projected medians are still below 3,580 feet, meaning sacred sites or archaeological sites—and any unknown sites—at these elevations would be exposed.

For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the highest water levels during both the Average and Critically Dry Flow Categories, followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has projected median elevations up to 1,150 feet in the Average Flow Category, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives have medians around 1,100 feet. In the Critically Dry Flow Category, all scenarios would expose sacred sites or archaeological sites and any unknown sites, but the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches)could protect more sites, with upper interquartile ranges reaching about 1,120 feet. Under the Representative Preferred Alternative, Lake Powell and Lake Mead elevations are comparable to other alternatives though Lake Mead elevations show greater variability across alternatives for the driest flow categories.

This pattern is reflected in the Preservation Risk Model analysis (**TA 11.2.2**). For Glen Canyon, the Enhanced Coordination Alternative is most robust, and will impact the fewest sites, with 30 percent of modeled futures in the initial modeling period staying below the preservation threshold, followed

by the Maximum Operational Flexibility Alternative at 25 percent. Under the Representative Preferred Alternative the preservation threshold is met in 16 percent of modeled futures. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust during the initial modeling period, with 5 percent of modeled futures meeting or staying below the threshold. The Maximum Flexibility Alternative and Representative Preferred Alternative both stay below the preservation threshold in 3 percent of modeled futures.

For the Colorado River stretches between Glen Canyon Dam and Lake Mead, and between Hoover Dam and Lake Mohave, water release volumes in Wet and Average Flow Categories generally remain within the range of past annual releases. However, in the Critically Dry Flow Category, median annual release volumes drop below 7.0 million acre-feet (maf) below Glen Canyon Dam, with the Enhanced Coordination Alternative reaching as low as 5.1 maf. Below Hoover Dam, median annual flows fall below 8.0 maf, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives dropping to 6.5 maf. As a result, in critically dry conditions, lower water levels increase the likelihood of sacred sites or archaeological sites near the riverbanks being exposed. The Representative Preferred Alternative has one of the narrowest interquartile range under critically dry hydrological conditions, with an upper limit around 6.0 maf, which is still below the bottom of the range of past flow volumes at 7.0 maf.

Below Davis Dam, impacts are expected to be minimal or nonexistent in any flow category. This is because the dams below Lake Mohave are managed to maintain lake elevations or meet targeted water deliveries, and many sections have channelized banks that further reduce exposure risks.

TA 13.2.4 Issue 3: How will changes in dam operations impact natural resources important to Native Americans including riparian vegetation and wildlife?

Indigenous worldviews do not differentiate between cultural and natural environments as does Western science. Under many Indigenous perspectives, resources considered separately as cultural or natural are all interconnected and interdependent (Berkes 2018). Human interventions that disrupt these interconnections are considered adverse impacts. This Final EIS discusses many of these resources such as water quality, air quality, and terrestrial wildlife among others. Although all resources are considered interconnected, Indigenous oral histories and ongoing consultation with Native American groups have identified riparian vegetation communities and aquatic wildlife as resource categories of particular concern along the Colorado River corridor. Accordingly, we consider riparian vegetation and aquatic wildlife (native and nonnative fish) below. Adverse impacts on these resources important to Native Americans would be addressed through ongoing consultation with affected tribes.

Quantitative impacts on riparian vegetation communities and evaluations of which alternatives best support historical vegetation community conditions are presented in detail in **TA 9**, Vegetation Including Special Status Species. Historical vegetation communities are those that prevailed in the decades prior to reservoir inundation and from Indigenous worldviews are the preferred condition. Those quantitative analyses from **TA 9** are summarized here. Woody riparian vegetation is moderately tolerant of water fluctuations, but if variability increases over a 5-year period, these areas

tend to decrease. Conversely, if water level variability decreases annually or over 5 years, woody riparian vegetation may expand.

For Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would maintain woody riparian vegetation most similar to historic conditions. For Lake Mead, the Maximum Operational Flexibility Alternative would best match historic vegetation patterns. However, in the stretch from Hoover Dam to the SIB reach, these two alternatives would cause vegetation to differ most from historic conditions, leading to greater changes in that area. The Basic Coordination Alternative would be least similar to historic conditions for Lake Powell but would be closest to historic vegetation patterns for Lake Mead and the Hoover Dam to SIB reach. The Representative Preferred Alternative would be least similar to historic conditions for Lake Powell and Lake Mead. This means no single alternative matches historic vegetation across all areas.

Most alternatives provide variability closer to historic conditions than the CCS Comparative Baseline in most reaches, except for Hoover Dam to SIB, where only the Basic Coordination Alternative does so. This suggests that changing current management strategies would benefit much of the analysis area.

For the stretch between Glen Canyon Dam and Lake Mead, which alternative best maintains historic vegetation depends on whether starting conditions are wet or dry. Under dry and critically dry conditions, differences between alternatives become more noticeable, especially in the lowest, median, and peak flows. However, across all alternatives, sub-reaches, and evaluation criteria (habitat area, native species richness, proportion of native species cover, and total annual vegetation cover), the interquartile ranges often overlap, making it hard to identify a clear best or worst alternative for preserving historic vegetation.

In all alternatives for Lake Powell, Lake Mead, and Hoover Dam to SIB, the first decade is expected to have greater variability and reduced woody riparian habitats compared to historic conditions. Conditions improve in the second and third decades, allowing vegetation to recover and reestablish. If variability prevents woody riparian habitats from forming, the area may shift to another habitat type.

Quantitative impacts on aquatic wildlife are considered in detail in **TA 8**, Biological Resources – Fish and Other Aquatic Resources, and those quantitative analyses are summarized here. Decreased water levels at Lake Powell affect lake and river habitats for culturally important native and nonnative fish. Among the alternatives, the No Action Alternative stands out because it increases the amount of exposed river habitat for endangered Colorado pikeminnow and razorback sucker, which is beneficial for these species. However, this also means less lake habitat for sportfish, which could negatively affect recreational fishing.

All alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives keep Lake Powell below critical elevation thresholds (3,598 feet for the Colorado River and 3,600 feet for the San Juan River), thereby increasing river habitat. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are less effective in this regard, as they tend to flood critical habitats and reduce the value of riverine habitat.

None of the alternatives are particularly successful at maintaining Piute Farms Waterfall as a barrier to prevent nonnative fish from moving upstream. On the other hand, all alternatives support native fish passage over the waterfall when it is inundated. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the CCS Comparative Baseline are the most effective at maintaining the waterfall as a barrier, while the Enhanced Coordination and Maximum Operational Flexibility Alternatives are more likely to allow inundation and fish passage.

For Lake Powell, the Representative Preferred Alternative provides moderate protection of riverine critical habitat but does not perform as well as the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches). Overall, it represents a moderate balance but is less robust than the best-performing alternatives for specific indicators.

For Lake Mead, the alternatives would affect tributary inflow habitats of culturally important fish populations. The No Action Alternative and CCS Comparative Baseline are the most effective at keeping Lake Mead below 1,090 feet for at least 90 percent of months. This helps restrict nonnative fish and maintain the current species composition in the Grand Canyon. However, these lower elevations also hinder native species—such as razorback sucker, flannelmouth sucker, and humpback chub—from moving upstream into Grand Canyon habitats.

The Basic Coordination Alternative performs moderately well in balancing these outcomes. In contrast, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are less effective, as they more often allow Lake Mead to rise above critical thresholds. This can make it easier for both native and nonnative fish to move upstream.

Among the alternatives, the Supply Driven Alternative (LB Pro Rata approach) is the most reliable for keeping Lake Mead above its historical minimum elevation, which supports greater habitat stability.

TA 13.2.5 Summary Comparison of Alternatives

TCPs are historic properties significant to Indigenous communities, mainly due to their association with culturally important events or individuals, as described in oral traditions. The main impacts on TCPs come from changes in the natural environment caused by managing reservoir levels and water releases, as well as increased exposure and visitation when water levels drop. Adverse impacts on TCPs are addressed through a programmatic agreement and ongoing consultation with tribes, in compliance with the National Historic Preservation Act.

As lake levels fluctuate, TCPs may become more accessible to both tribal members and non-Native visitors. Under wet conditions, most alternatives keep Lake Powell's water levels high and exposure of TCPs low, except for the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which has lower elevations. In dry conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain the highest water levels, limiting TCP exposure, while the No Action and Basic Coordination Alternatives result in lower elevations and greater access to TCPs. For Lake Mead, water levels also drop as conditions get drier. The Supply Driven Alternative (LB Pro Rata approach) keeps the highest water levels and limits TCP exposure,

while the No Action Alternative and CCS Comparative Baseline have the lowest levels, increasing access to TCPs. Under the Representative Preferred Alternative, Lake Powell and Lake Mead elevations remain relatively stable compared to other alternatives with increasing variability in the driest flow categories.

Sacred sites are locations identified by tribes for the sites' religious or ceremonial significance, and they often overlap TCPs and Indigenous archaeological sites. Impacts on sacred sites are similar to those affecting archaeological sites, with the main concerns being damage from wave action and wet-dry cycling caused by fluctuating lake and river levels. Continuous inundation helps preserve these sites, while exposure due to falling water levels increases risks.

During wet conditions, Lake Powell's water levels are expected to remain high, minimizing exposure. As conditions become drier, the Enhanced Coordination and Maximum Operational Flexibility Alternatives maintain higher water levels than others but still fall below critical thresholds in extremely dry scenarios, exposing more sites. For Lake Mead, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) maintains the highest water levels and protects more sacred sites, especially in dry conditions. For river stretches between Glen Canyon Dam and Lake Mead, and between Hoover Dam and Lake Mohave, annual water releases in wet and average years generally match historical volumes. In critically dry years, releases drop significantly, increasing the risk of exposing sacred and archaeological sites near riverbanks. Below Davis Dam, impacts are minimal due to managed lake elevations and channelized banks.

Indigenous perspectives view cultural and natural resources as interconnected, so any disruption to these links is a potential impact. Along the Colorado River, riparian vegetation and aquatic wildlife are especially important to Native Americans. Woody riparian vegetation is moderately resilient to water fluctuations, but increased variability over several years can reduce these habitats. For Lake Powell, the Enhanced Coordination and Maximum Operational Flexibility Alternatives best maintain vegetation similar to historic conditions. For Lake Mead, the Maximum Operational Flexibility Alternative performs best, while the Basic Coordination Alternative is closest to historic conditions for Lake Mead and the Hoover Dam to SIB reach. No single alternative matches historic vegetation patterns across all areas, but most alternatives perform better than the CCS Comparative Baseline in most reaches. The Representative Preferred Alternative would be least similar to historic conditions for Lake Powell and Lake Mead.

Lower water levels at Lake Powell benefit endangered river species (Colorado pikeminnow and razorback sucker) by increasing their habitat, especially under the No Action Alternative, but this reduces lake habitat for sportfish. Most alternatives (except the Enhanced Coordination and Maximum Operational Flexibility Alternatives) keep Lake Powell below critical thresholds, favoring river habitats. The Enhanced Coordination and Maximum Operational Flexibility Alternatives tend to flood critical habitats, reducing river habitat value. For Lake Mead, the No Action Alternative and CCS Comparative Baseline maintain lower water levels, helping restrict nonnative fish but also limiting upstream movement of native fish. The Basic Coordination Alternative offers a moderate balance. Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives more often allow Lake Mead to rise above critical thresholds, which can facilitate movement for both native and nonnative fish. The Supply Driven

Alternative (LB Pro Rata approach) is most reliable for maintaining Lake Mead above its historic minimum, supporting habitat stability. Overall, the Representative Preferred Alternative provides moderate protection of riverine critical habitat but does not perform as well as the Supply Driven Alternative (LB Pro Rata approach).

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Technical Appendix 14

Recreation

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS
2024 LTEMP Final SEIS	Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement
°C	degrees Celsius
°F	degrees Fahrenheit
CCS	Continued Current Strategies
cfs	cubic feet per second
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
FWS	United States Fish and Wildlife Service
GCNP	Grand Canyon National Park
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
LTEMP	Long-Term Experimental and Management Plan
NIB	Northerly International Boundary
NPS	National Park Service
NRA	National Recreation Area
NWR	National Wildlife Refuge
Reclamation	Bureau of Reclamation
RM	river mile
SEIS	supplemental environmental impact statement
SIB	Southerly International Boundary
UDOT	Utah Department of Transportation

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TA 14. Recreation

TA 14.1 Affected Environment

This Final Environmental Impact Statement (EIS) identifies and describes in detail the following key recreation resources or issues:

- Shoreline public use
- Reservoir boating
- River and whitewater boating
- Sportfishing

TA 14.1.1 Shoreline Public Use

The following sections describe shoreline public use associated with boating facilities (marinas, boat docks, and boat launch ramps), access to points of interest, and other opportunities within each Colorado River reach. Recreational boating in the study area depends on these major shoreline access points. While fluctuations in pool elevations are a normal aspect of dam operations, increased frequency or severity of these variations could result in changes in recreational facility operational costs and temporary closures. Below critical pool elevations and river flows, certain facilities may be rendered inoperable or require relocation to maintain operation.

Lake Powell and Glen Canyon Dam

Lake Powell is entirely within the Glen Canyon National Recreation Area (NRA), which receives approximately three to five million visitors each year (NPS 2025a). **Table TA 14-1** summarizes visitation to Glen Canyon NRA from 2019 through 2024.

Table TA 14-1
Glen Canyon NRA Recreational Visitors

Year	Recreational Visitors
2019	4,330,563
2020	2,553,392
2021	3,144,318
2022	2,842,776
2023	5,206,934
2024	4,725,610

Source: NPS 2025a

Table TA 14-2 summarizes the total number of recreational visits to Glen Canyon NRA by district for 2024, which is the most recent year for which data are available.

Table TA 14-2
Glen Canyon NRA Visits by District for 2024

District	Recreational Visitors
Wahweap District	1,612,518
Antelope Point District	532,202
Bullfrog District	101,627
Halls Crossing District	139,234
Hite District	261,725
Lees Ferry District	2,065,278
Horseshoe Bend District	831,631
Escalante District	13,029

Source: NPS 2025b

Lake Powell, with its many side canyons and related natural, cultural, and geological resources, is Glen Canyon NRA's primary recreational feature. Recreation that occurs at Lake Powell includes swimming and sunbathing, power boating, waterskiing, fishing, off-beach activities associated with boat trips (such as hiking and exploring archaeological sites), house boating, personal watercraft use, canoeing, kayaking, sailing, wildlife viewing, photography, sightseeing, and other activities. Visitors can enjoy a wide range of camping options, from remote and undeveloped campsites to fully developed campgrounds. Visitors can also see archaeologically and culturally important sites throughout Glen Canyon NRA.

Boating Facilities

Recreational boating is the most important recreational activity on Lake Powell, with nearly two million visitors accessing the reservoir by either private boat or rental (NPS 2025c). **Table TA 14-3** lists critical lake elevations for Lake Powell, identified by the National Park Service (NPS), below which certain marinas, boat docks, or boat launch ramps become inoperable. Water-based recreational facilities at Lake Powell include the marinas at Wahweap, Halls Crossing, Bullfrog, and Antelope Point. Declining water levels have rendered the Dangling Rope Marina inoperable since 2021; prior to its closure, it was the busiest gas station in Utah, despite lacking road access, because it served as the only refueling location in the middle of the lake. The Hite Launch Ramp has also been closed since 2012 due to the ramp being out of the water as a result of low reservoir levels (NPS 2025d).

Changes to the shoreline affect the usability of boat launch ramps throughout the year, especially in warmer months. Launch ramp closures due to declining water levels have resulted in longer lines, limited parking, and congestion at boat ramps and docks (NPS 2025d).

Table TA 14-3
Critical Elevations for Lake Powell by Boating Facility

Lake Elevation (feet)	Impact and Facility
3,700	Full pool
3,650	Hite Public Launch Ramp closed
3,588	Antelope Point Public Launch Ramp closed
3,583	Castle Rock Cut closed
3,578	Bullfrog Main Launch Ramp and Spur closed
3,565	Utah Department of Transportation (UDOT) Ferry and Launch Ramp closed
3,564	Wahweap Stateline Launch Ramp closed
3,556	Hall's Crossing Main Launch Ramp closed
3,550	Wahweap Main Launch Ramp closed; Rainbow Bridge National Monument closed
	Bullfrog Main Launch Ramp Spur closed
3,540	Antelope Point Business Ramp closed
3,529	Bullfrog North Launch Ramp closed
3,520	Wahweap Stateline Auxiliary Launch Ramp closed
3,515	Antelope Marina closed; Bullfrog Marina closed; Hall's Crossing Marina closed
3,430	Wahweap Boat Rental closed; Wahweap Boat Tour Dock closed

Source: Nicole Gibney, Assistant Colorado River Coordinator, NPS, personal communications, May 15, 2024

In 2022, the NPS received $26 million in Disaster Supplemental Funding to provide additional boating access at Lake Powell. Design work is underway for a north Lake Powell ramp that provides access down to an elevation of 3,450 feet in the Stanton Creek area near Bullfrog. The NPS is also working to develop schematic designs for the Antelope Point Public Ramp, Halls Crossing Public Ramp, and a primitive ramp and take-out area at the Hite Marina. The NPS continues to seek funding necessary for potential reconstruction. The NPS is also continuing to seek funds to replace the services previously offered at Dangling Rope Marina and for a navigable waterway congestion study in south Lake Powell (NPS 2023a).

State Route 276 runs through Glen Canyon NRA and crosses Lake Powell via the Charles Hall Ferry, which the UDOT operates. The ferry's southern port is at Hall's Crossing, and the northern port is at Bullfrog. The ferry does not operate if Lake Powell elevation levels drop below 3,565 feet (UDOT 2025).

Access to Points of Interest

Since 2021, the courtesy dock access to the Rainbow Bridge National Monument trail has been intermittently unavailable due to changes in the water level. When water levels fall below 3,544 feet, visitors have to leave boats and small vessels at the shoreline and traverse through mud, debris, sand, and water before reaching the established trail. While no longer connected to the shoreline, the Rainbow Bridge dock system is accessible with restroom facilities. The concessionaire-operated

tours to the monument are no longer able to access the area, thus removing access for most Glen Canyon NRA visitors. Visitors can also access Rainbow Bridge National Monument by obtaining a permit from the Navajo Nation Parks and Recreation Department to backpack for multiple days on Navajo Tribal lands from Navajo Mountain; however, this is not possible for many visitors (NPS 2021).

Harmful Algal Blooms

Warming water temperatures and increased inputs of nutrients from monsoonal storms create conditions that are more conducive to harmful algal bloom growth in freshwater bodies, also known as cyanobacterial blooms. Harmful algal blooms produce toxins that pose serious health risks to humans and animals (NPS 2019). Harmful algal blooms may necessitate temporary closures of water-based recreation to protect public health (Deemer et al. 2023). Water quality concerns are described in detail in **TA 6**, Water Quality.

Quagga Mussel Shells on Shorelines

Quagga mussels were first detected at Lake Powell in 2012. Quagga mussels have colonized practically all areas of the lake, as indicated by water sampling for veligers (NPS 2023b). Seasonally low water levels are now exposing mussel-encrusted shoreline. Sharp quagga mussel shells eventually wash up on beaches and can cut through skin, clothing, and pet paws (NPS 2016).

Hiking and Sightseeing in Glen Canyon

Declining water levels have exposed approximately 100,000 acres of Glen Canyon that were previously inundated by Lake Powell, creating new opportunities to view landscapes that have been underwater since the late 1960s (Baker 2022; Kolbert 2021). These include arches, side canyons, other rock formations, and lush desert ecosystems. This has created new hiking and sightseeing opportunities for Glen Canyon NRA visitors over the last several years. At the same time, these landscapes and archaeological sites are fragile, and exposure could result in their degradation and vandalism.

TA 14.1.2 Glen Canyon Dam to Lake Mead

The 15.5-mile river reach downstream of Glen Canyon Dam to Lees Ferry is within Glen Canyon NRA; it is used by anglers, campers, commercial float trip operators, kayakers, and other boaters. Fishing opportunities for rainbow and brown trout also occur downstream of this reach. In the last 5 years, warming water temperatures have made this reach more attractive for day and overnight use by paddleboarders, kayakers, and canoeists, resulting in increased visitation.

The NPS manages most of the reach, except where it is bordered on the east by the Navajo Indian Reservation and on the south by the Hualapai Indian Reservation. Grand Canyon National Park (GCNP) staff regulates visitor use of the Colorado River downstream of Lees Ferry in accordance with the Colorado River Management Plan (NPS 2006a, 2006b).

GCNP begins downstream of the Lees Ferry boat ramp at the confluence of the Colorado and Paria Rivers. Designated as a United Nations Educational, Scientific and Cultural Organization World Heritage Site in 1979, GCNP is valued for its superlative natural and cultural resources as well as its varied recreational experiences. Approximately 94 percent of GCNP (1,143,918 acres) qualifies as

wilderness, as described in the 1964 Wilderness Act (Public Law 88-577) and NPS Management Policies 2006 (NPS 2006b). This includes 10,919 acres of potential wilderness along the Colorado River corridor.

The Colorado River corridor borders tribal lands for nearly half the distance from the put-in at Lees Ferry to the last takeout at Pearce Ferry. The Navajo Indian Reservation borders GCNP along the eastern bank of the Colorado River from near Lees Ferry to the confluence with the Little Colorado River at river mile (RM) 61.8. The Hualapai Indian Reservation borders the river corridor for approximately 108 miles from upstream of National Canyon (RM 167) to approximately RM 274. The Hualapai Indian Reservation offers camping, fishing, hiking, and big game hunting. Tribal enterprises offer rafting trips on the Colorado River between Diamond Creek and Pearce Ferry. The NPS coordinates with tribal neighbors to address resource management and visitor use concerns along shared boundaries. Access permits from the Navajo Nation, Havasupai Tribe, or Hualapai Tribe are required by each respective tribe to access and recreate on tribal lands.

GCNP receives four to six million visitors each year (NPS 2025e). **Table TA 14-4** summarizes visitation to GCNP from 2019 to 2024.

Table TA 14-4
GCNP Recreational Visitors

Year	Recreational Visitors
2019	5,974,411
2020	2,897,098*
2021	4,532,677
2022	4,732,101
2023	4,733,705
2024	4,919,163

Source: NPS 2025e
*Park closure April–May due to the COVID-19 pandemic

The Lees Ferry to Diamond Creek reach has relatively low-use densities (attributed to the competitive lottery system) and low levels of development, providing opportunities for solitude on the Colorado River; this reach also offers many camps and attraction sites. This section of the Colorado River is where the majority of whitewater boating occurs. Takeouts are at Diamond Creek and Pearce Ferry. The reach downstream of Diamond Creek offers different recreational opportunities than the upstream reach, as it transitions to a more populated, developed setting. Whitewater boating trips become intermingled with very high levels of general boating and recreational use in the Quartermaster area (RM 260). **TA 16**, Socioeconomics, describes the social and economic importance of whitewater boating in the Grand Canyon.

Helicopter operations authorized by the Hualapai Tribe transport people into the Grand Canyon and connect them with motorized pontoon boats that give 20-minute tours of the Quartermaster area. These helicopters also fly out boaters who complete commercial motor day trips from Diamond Creek.

Boating Facilities

No boating facilities are within GCNP. Development along the Colorado River within the park is limited to the development at Phantom Ranch (RM 88) and Pipe Creek (RM 89.5). Other focal points include the launch ramp at Lees Ferry (within Glen Canyon NRA), the helipad near Whitmore Wash (RM 187) on the Hualapai Reservation, road access and minor structures operated by the Hualapai Tribe at Diamond Creek (RM 226), and the tourist area near Quartermaster Canyon (RM 260).

Camping between the Lees Ferry boat ramp and Lake Mead occurs in GCNP on undeveloped sandbars along the Colorado River. The number and usability of campsites diminish between depositional high-flow experiments, due to vegetation encroachment, sandbar erosion from hydropeaking operations, erosion from tributary flooding, aeolian sand remobilization, and recreational use.

Ongoing Glen Canyon Dam operations have resulted in encroachment of vegetation onto sandy beaches. One species that poses particular problems related to campsite encroachment is arrowweed (*Pluchea sericea*), a native shrub that can readily colonize open sandbars used as campsites. Further information on arrowweed and vegetation encroachment can be found in **TA 9**, Vegetation Including Special Status Species.

Sites can also be closed to protect sensitive resources (NPS 2006a). Further information on sedimentation and beach building can be found in **TA 5**, Geomorphology and Sediment. Of the 276 campsites referenced in Section 3.12.1.1 of the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS (2007 Final EIS), 195 sites (71 percent) are still classified as "camps";[1] 68 sites (25 percent) have been classified as "noncamps" due to sand erosion, vegetation overgrowth, or both; 2 sites could not be ascertained based on the float-by methodology used during the November 2022 NPS Colorado River Management Plan monitoring trip; and 10 campsites were not evaluated (Kearsley 2023).

TA 14.1.3 Lake Mead and Hoover Dam

Lake Mead NRA encompasses 1.5 million acres. It encompasses the 110-mile-long Lake Mead, the 67-mile-long Lake Mohave, the surrounding desert, and the isolated Shivwits Plateau in Arizona. Recreation such as camping, boating, fishing, and hiking occurs on upper Lake Mead. The Overton Wildlife Management Area provides opportunities for wildlife viewing and photography, waterfowl and upland game-bird hunting, hiking, and fishing. The Overton Wildlife Management Area averages 4,226 annual visitor use days.[2]

Lake Mead NRA extends along the lower Colorado River from GCNP's western border to Davis Dam. The primary recreational activities on Lake Mead include cruising/sailing, personal watercraft usage, waterskiing, fishing, and swimming. A number of campgrounds and picnic areas, including Boulder Beach, Calville Bay, Echo Beach, Las Vegas Bay, and Temple Bar, provide additional

[1] Campsite area is defined as any region of smooth substrate (most commonly sand) with no more than an 8-degree slope and little or no vegetation (Kaplinski et al. 2014).
[2] Nevada Department of Wildlife, personal communication, 2023

recreational opportunities. Lake Mead NRA had approximately 6.4 million visitors in 2024 (NPS 2025f).

Table TA 14-5 summarizes recreational visits to Lake Mead NRA for 2019 to 2024.

Table TA 14-5
Lake Mead NRA Recreational Visitors

Year	Recreational Visitors
2019	7,499,049
2020	8,016,510
2021	7,603,474
2022	5,578,226
2023	5,798,541
2024	6,412,854

Source: NPS 2025f

Water quality concerns are increasing and are described in detail in **TA 6**, Water Quality. In the spring and summer of 2015, Lake Mead experienced notable concentrations of harmful blue-green algae, which triggered harmful algal bloom advisories for various locations across the lake (NPS 2023b). In 2022, a swimmer was fatally infected with a brain-eating amoeba (*Naegleria fowleri*) at Lake Mead. Brain-eating amoebas are commonly found in bodies of warm, fresh water, such as lakes, rivers, and geothermal water (NPS 2022). These trends may continue to increase as water temperatures warm.

Declining reservoir elevations at Lake Mead in recent years have exposed mudflats along several areas of the shoreline. These have created dangerous conditions where recreationists have periodically become stuck in wet, muddy deposits. Some of these areas have access roads that previously enabled visitors to drive close to the shoreline when reservoir elevations were higher. As reservoir elevations have declined over recent years, visitors have often attempted to chase the shoreline both in their vehicles and on foot to gain access to the changing shoreline for such purposes as fishing, hiking, and other recreational activities. In doing so, they and their vehicles have created unauthorized vehicle routes toward the lowering water levels, and they have become stuck in these muddy conditions, requiring assistance from NPS personnel and others to extract themselves and/or their vehicles.

Boating Facilities

Lake Mead NRA is considered one of the nation's premier water-based recreation areas. Most visitors participate in water-based recreational activities, primarily between May and September. These recreational activities are supported by marina and launch ramp facilities developed along the Lake Mead shoreline. On average, the majority of boats are personal watercraft. Water-based recreational facilities at Lake Mead are located at Callville Bay, Hemenway Harbor, Temple Bar, Echo Bay, South Cove, and Pearce Ferry boat ramps. Pearce Ferry is used as a takeout by Colorado River boaters.

Table TA 14-6 shows critical elevations identified by the NPS for Lake Mead, below which marinas, boat docks, or boat launch ramps become inoperable. The Pearce Bay launch ramp, a take-out point for rafts and whitewater boats, is closed at 1,175 feet. This results in rafts and other whitewater boats having to continue downstream to South Cove, which is an additional 16 miles.

Table TA 14-6
Critical Elevations for Lake Mead by Boating Facility

Lake Elevation (feet)	Impact and Facility
1,221	Full pool
1,075	Boulder Harbor closed
1,035	South Cove Ramp closed
1,000	Echo Bay public launch ramp closed
950	Hemenway Harbor public launch ramp closed; Callville Bay public launch ramp closed; Temple Bar public launch ramp closed

Source: Nicole Gibney, Assistant Colorado River Coordinator, NPS, personal communications, May 15, 2024; December 3, 2024; and December 10, 2025

Since the publication of the 2007 Final EIS, the Echo Bay, Boulder Harbor, and South Cove boat ramps have closed due to low water levels. The NPS facilities at the Temple Bar Marina are also inoperable; however, the concessionaire's launch operations remain operable. The Pearce Bay launch ramp, a take-out point for rafts and whitewater boats, previously closed at elevation 1,175 feet. Access to Lake Mead was closed at Pearce Ferry in 2001 when the water elevation dropped to 1,175 feet. In 2010, the NPS extended Pearce Ferry Road 2 miles to the Colorado River to provide for river take-out operations for private and commercial river runners (NPS 2010).

Changes to water levels affect the usability of the remaining boat launch ramps throughout the year, especially in warmer months. Launch ramp closures due to declining water levels have resulted in longer lines, limited parking, and congestion at boat ramps and docks. In addition, ongoing maintenance and construction at ramps have resulted in temporary closures.

TA 14.1.4 Hoover Dam to Davis Dam

Visitation and recreational use at Lake Mohave have increased in response to more variable Lake Mead levels and the closure of associated boating infrastructure. Recreational opportunities at Lake Mohave include boating, canoeing on the northern parts of the lake, camping, exploring, fishing, photography, picnicking, swimming, parasailing, and waterskiing. There are also hundreds of beaches accessible only by boat. As with Lake Mead, harmful blue-green algal blooms occurred at Lake Mohave in 2015, leading to advisories for multiple locations across the lake (NPS 2023b).

The main shoreline access points for Lake Mohave are Katherine Landing, Cottonwood Cove, and Willow Beach. Facilities for public use and boat launching are located at Katherine's Landing in Arizona near Davis Dam and at Cottonwood Cove, which is east of Searchlight, Nevada. Boats and jet skis can be rented at both locations. Public campgrounds are available at both locations, where concessionaires provide trailer parks, restaurants, lodging, docking facilities, boat and fishing tackle

equipment, and fishing licenses. Facilities for public use and boat launching are also at Willow Beach, 31 miles upstream on the Arizona shore.

TA 14.1.5 Davis Dam to Parker Dam

The Davis Dam to Parker Dam reach includes several recreational areas along the Colorado River, including Laughlin, Bullhead City, Davis Camp, Needles, Havasu National Wildlife Refuge (NWR), Lake Havasu State Park, and Bill Williams River NWR. Relevant recreational areas are briefly described in the following sections.

Davis Camp. Davis Camp contains a campground and day use area. It has boat launching facilities, picnic areas, numerous campsites, and recreational vehicle hookups. Davis Camp offers many river-oriented recreational opportunities, including fishing and water sports.

Havasu NWR. The Havasu NWR, managed by the United States Fish and Wildlife Service (FWS), covers 30 RMs (300 miles of shoreline) from Lake Havasu City, Arizona, to Needles, California. Typical activities include canoeing, fishing, boating through the scenic Topock Gorge, and hiking in the Havasu Wilderness Area. The 4,000-acre Topock Marsh offers excellent canoeing, fishing, and bird-watching. Other activities offered at the Havasu NWR include camping and hunting.

Lake Havasu State Park. Formed by Parker Dam, Lake Havasu contains several coves and inlets and is a popular spot for fishing. Lake Havasu's waters are also used for canoeing, houseboating, riding watercrafts, kayaking, sailing, speedboating, swimming, and waterskiing. Camping and hiking also occur along the more than 400 miles of the lake's shoreline. Additional visitor opportunities include viewing the London Bridge. Lake Havasu is a popular destination for spring break and family vacations.

Lake Havasu is the premier attraction area within the Davis Dam to Parker Dam reach. **Table TA 14-7** lists the visitation from 2019 to 2024 at Arizona's Lake Havasu and Cattail Cove State Parks.

Table TA 14-7
Visitation at Arizona's Lake Havasu and Cattail Cove State Parks

Year	Lake Havasu State Park Visitation	Cattail Cove State Park Visitation
2019	488,597	111,262
2020	598,403	116,822
2021	492,074	95,179
2022	494,318	86,385
2023	484,716	79,978
2024	468,535	83,992

Source: Arizona Hospitality Research and Resource Center 2025

Bill Williams River NWR. Managed by the FWS, the Bill Williams River NWR is along the Bill Williams River near its confluence outlet into Lake Havasu. The refuge offers a variety of recreational opportunities, including hiking, bird-watching, and other wildlife viewing. Hunting is

permitted for dove, cottontail, quail, and desert bighorn sheep. Other activities include boating and fishing.

Boating Facilities. The Davis Dam to Parker Dam reach includes shoreline public use facilities at Laughlin, Bullhead City, Davis Camp, Needles, Havasu NWR, Lake Havasu State Park, and Bill Williams NWR. Recreational activities within this reach include canoeing, fishing, houseboating, riding watercrafts, kayaking, sailing, speedboating, swimming, and waterskiing.

TA 14.1.6 Parker Dam to Cibola Gage

The Parker Dam to Cibola Gage reach includes several recreational areas, including Parker Strip Recreation Area, Palo Verde Diversion Dam, Blythe, and the Cibola NWR. The following are brief descriptions of the relevant recreational areas on this reach.

Parker Strip Recreation Area. The Parker Strip Recreation Area includes an 11-mile road along the Colorado River. Recreation includes boating, camping, fishing, hiking, rock hounding, swimming, and wildlife viewing.

Palo Verde Diversion Dam. There are approximately 95 miles of navigable waters between Imperial Dam downstream of Yuma and Palo Verde Diversion Dam upstream of Blythe. Activities include canoeing, fishing, hunting, power boating, and other water sports.

Cibola NWR. The Cibola NWR, including Cibola Lake, is managed by the FWS and located about 15 miles south of Blythe. Visitors to the refuge engage in canoeing, fishing, hiking, hunting, photography, and wildlife viewing.

Boating Facilities. The Parker Dam to Cibola Gage reach includes shoreline public use facilities at Parker Strip Recreation Area, Palo Verde Diversion Dam, Blythe, and the Cibola NWR. Typical water activities within this reach include canoeing, power boating, fishing, swimming, and other water sports.

TA 14.1.7 Cibola Gage to Imperial Dam

The Cibola Gage to Imperial Dam reach includes the following few recreational areas: Picacho State Recreation Area, Imperial NWR, and Martinez Lake. Brief descriptions of these recreational areas follow.

Picacho State Recreation Area. This area is popular for camping, desert exploring, river running, and sportfishing. It received approximately 10,763 visitors in 2022 (including day and overnight use),[3] and it has a group boat-in area, three individual boat-in camp areas, and large group camping areas. Bird-watching and small-game hunting for doves, ducks, and quail are among the other recreational opportunities.

Imperial NWR. Recreational opportunities at the Imperial NWR include canoeing, fishing, and hunting. Boaters value the refuge for its remote scenery.

[3] T. Unzicker, personal communication, December 5, 2024.

Martinez Lake. Martinez Lake, which adjoins the Imperial NWR, offers opportunities for fishing, bird-watching, boating, hunting, rock hounding, sightseeing, and waterskiing.

Boating Facilities. The Cibola Gage to Imperial Dam reach includes shoreline public use facilities at Picacho State Recreation Area, Imperial NWR, and Martinez Lake. Typical water activities within this reach include river running, boating, canoeing, waterskiing, and sportfishing.

TA 14.1.8 Imperial Dam to the Northerly International Boundary (NIB)

The Imperial Dam to the NIB reach includes a few recreational areas along the Colorado River, including Betty's Kitchen and Mittry Lake Wildlife Area. The following are brief descriptions of these recreational areas.

Betty's Kitchen. This 10-acre wildlife interpretative area provides bird-watching and fishing opportunities.

Mittry Lake Wildlife Area. Mittry Lake, within the Mittry Lake Wildlife Area, covers approximately 600 acres and provides small-game hunting and sportfishing opportunities. There is a three-lane boat launch ramp for motorized boating on the lake. The area is also popular for bird-watching and nature study.

Boating Facilities. The Imperial Dam to the NIB reach includes shoreline public use facilities, including a public fishing pier at Betty's Kitchen and a boat launch ramp for motorized boating and fishing jetties at Mittry Lake Wildlife Area. Typical water activities within this reach include boating, swimming, and sportfishing.

NIB to the Southerly International Boundary (SIB)

The NIB to the SIB reach includes shoreline public use facilities in the city of Yuma, Arizona. Typical water activities within this reach, which is on the edge of the historical floodplain to the east of the Colorado River, include boating, swimming, and sportfishing.

TA 14.1.9 Reservoir Boating

Reservoir boating is affected by fluctuating reservoir elevations; these fluctuations specifically alter exposure to boating navigational hazards and safer boating capacities. Hazards such as exposed rocks may become more evident, and changes in navigational patterns may be necessary as reservoir elevations decline. At low-pool elevations, special buoys or markers may be placed within reservoirs to warn boaters of navigational hazards. In addition, signs may be posted in areas deemed unsuitable for navigation.

Near Hite, a delta has formed that can affect river boaters coming into Lake Powell at low-pool elevations. River boaters from the Colorado River row or motor through Lake Powell to a location where a boat transports them 20 to 25 miles to the Hite Marina. At low elevations, the river boaters must travel farther downstream to reach a location accessible to the transport company's boat. Although this results in more miles to the takeout, there is usually enough current in the river to carry the boats. At lower elevations, additional rapids are exposed in Cataract Canyon. Lower Lake Powell elevations may create additional navigational hazards due to restricted channel widths and subsurface conditions.

Lake Powell

Safe boating navigation. The navigation system on Lake Powell uses regulatory buoys and other marking devices to warn boat operators of hazardous conditions associated with subsurface obstructions or changes in subsurface conditions that could be hazardous for safer passage. Placement of many of these marking devices depends on the lake's elevation.

Lake Mead

Safe boating navigation. Regulatory buoys and other marking devices are used on Lake Mead to warn boat operators of dangers, obstructions, and changes in subsurface conditions in the main channel or side channels. Excursions from Lake Mead into the Grand Canyon are a popular activity. Boats entering the Grand Canyon usually launch at Pearce Ferry, South Cove, or Temple Bar. Many boaters include overnight camping on these excursions.

The upper arms and inflow areas of Lake Mead may be difficult to navigate due to shifting subsurface sediments. Over the years, sediment has built up in the section of the reservoir between Grand Wash and Pearce Ferry. When Lake Mead elevations drop below 1,170 feet, the sediment is exposed as mud flats, and there is no well-defined river channel. As a result, the area is too shallow for motorboats to navigate upstream and into the lower reaches of the Grand Canyon. With fluctuating flows, even smaller crafts may have difficulty accessing the area due to the shifting channel. Based on this information, an elevation of 1,170 feet is considered a threshold elevation for safer boating navigation for Lake Mead's upper end.

Since the publication of the 2007 Final EIS, the NPS has extended the Pearce Ferry launch ramp to provide river take-out operations for private and commercial river runners. However, due to the proximity of the developing Pearce Ferry Rapid, the public launch of boats is prohibited (NPS 2010).

Lake Mohave and Lake Havasu

Because Lake Mohave and Lake Havasu will continue to be operated to meet monthly target elevations, the alternatives will not affect reservoir boating and navigation in these reaches beyond the trends previously described.

TA 14.1.10 River and Whitewater Boating

Whitewater boating is the key recreational activity in the Grand Canyon from Lees Ferry to the Diamond Creek or Pearce Ferry takeouts. Other reaches are not predominantly whitewater localities; therefore, they will not be discussed in this section.

Glen Canyon Dam to Lake Mead

Grand Canyon whitewater boating trips launch at Lees Ferry in Glen Canyon NRA and take out at Diamond Creek on the Hualapai Indian Reservation or at Pearce Ferry in Lake Mead NRA. River trips are conducted using a variety of boats and rafts; group sizes can range up to 32 people (including guides). Trip lengths range up to 25 days and can be run by commercial companies or by private individuals. There are various ways to join trips, including launching from Lees Ferry, hiking into or out of the canyon to join and leave a trip, and gaining limited access by vehicle and helicopter (commercial use only) to join trips in the western portion of the Grand Canyon.

GCNP staff regulates recreational boating in accordance with the Colorado River Management Plan (NPS 2006a). The Colorado River Management Plan prescribes management of recreational use by establishing limits on the number of daily launches, group size, trip length, and periods of motorized and nonmotorized use. Motorized use is permitted between April 1 and September 15. In general, whitewater navigability can be affected by river flows and by large amounts of side canyon debris washed into the river channel. Due to reduced water levels in Lake Mead, rapids like Separation Rapid have returned, and new rapids have formed from the Colorado River scouring a new path in the deltaic sediments, making it more challenging to navigate. While most of the river still follows the old river channel, a new channel has developed near Pearce Ferry, creating a new impassible class VI rapid known as the Pearce Ferry Rapid (Joel 2016). A new waterfall or rapid is expected to form downstream from the North Wash boat ramp that serves as the take-out point for Cataract Canyon rafters (Returning Rapids Project 2023). Intermittent, larger-volume, and higher-magnitude flows could improve navigability at some of these rapids.

River flow levels and fluctuations are important for whitewater boaters (Bishop et al. 1987; Shelby et al. 1992; Hall and Shelby 2000; Stewart et al. 2000; Neher et al. 2017). Past studies have polled commercial and private whitewater trip leaders for their preferences on the minimum levels for running the river safely with passengers. Preferences may vary by experience level and equipment types for different boaters, but a majority have reported that flows below 10,000 cubic feet per second (cfs) and above about 45,000 cfs are considered less than optimal; flows between 20,000 and 26,000 cfs are considered optimum (Shelby et al. 1992; Bishop et al. 1987; Neher et al. 2017). Flows above 8,000 cfs have been identified by commercial guides as the minimum level necessary to safely run the river with passengers (Shelby et al. 1992; Stewart et al. 2000). At low flows (5,000 cfs or less), it often becomes necessary to either walk passengers around some rapids or wait for higher water. The risk of accidents varies by the type of boat employed. At extremely low flows (less than 5,000 cfs), motor rigs have the highest incidence of accidents, followed by small (typically private group) rafts (Jalbert 1992). At flows higher than power plant capacity, smaller craft, such as small rafts, dories, kayaks, and canoes and inflatables, experience more accidents (Brown and Hahn-O'Neill 1987).

Hoover Dam to SIB

The alternatives are not expected to adversely affect river and whitewater boating between Hoover Dam and the SIB.

TA 14.1.11 Sportfishing

No specific reservoir elevation thresholds or river stages related to sportfishing were identified in the literature reviewed. Catch rates for reservoir fishing are assumed to be directly related to reservoir habitat, including water quality. Please refer to **TA 8**, Biological Resources – Fish and Other Aquatic Resources, for more information regarding impacts on fish habitat, and **TA 6**, Water Quality, for impacts on water quality. Fishing satisfaction is assumed to be directly related to (1) the general recreational issues of boating access to water via shoreline facilities, and (2) the potential for boating navigational hazards or reservoir detours due to low reservoir elevations.

Lake Powell and Glen Canyon Dam

Lake Powell supports a popular warmwater sportfishery composed mainly of striped and smallmouth bass. The striped bass depends on threadfin shad for a significant portion of their diet. The threadfin shads in Lake Powell are at the northernmost portion of their range, and they are sensitive to fluctuations in water temperature. Gizzard shads may become an important forage fish for striped bass. In addition to striped and smallmouth bass, Lake Powell supports other nonnative fish species, including largemouth bass, walleye, channel catfish, bluegill, and black crappie. Angler use in 2018 was at a 40-year low, mainly attributed to a decline in the percentage of boat days that were spent angling (Blommer and Gustaveson 2021).

Glen Canyon Dam to Lake Mead

The 15.5-mile Glen Canyon reach of the Colorado River supports a Blue Ribbon recreational rainbow trout fishery that attracts local, national, and international anglers. The NPS, in coordination with the Arizona Game and Fish Department and the FWS, manages fish in all waters within Glen Canyon NRA and GCNP. The intention of Blue Ribbon management is to provide a quality fishing opportunity where anglers can catch larger-than-average trout at a relatively high catch rate in a unique recreational setting. Most angling is from boats or is facilitated by boat access, often provided by guide services. Some anglers also wade or fish from shore.

Fishing in the Glen Canyon reach occurs year-round. Peak usage is in April and May; however, substantial fishing has occurred from March through October in most years (Rogowski and Boyer 2023). An estimated 5,095 anglers used the rainbow trout fishery in 2022; of these, 3,594 were boat anglers, and 1,501 were walk-in anglers (Rogowski and Boyer 2023). Boat and walk-in angler use decreased in 2022 relative to 2021 (Rogowski and Boyer 2023).

The quality of the rainbow trout fishery at Lees Ferry is highly dependent on water quality within the reach, which is a proxy for catch (Bishop et al. 1987). Prior to 2022, fish species from Lake Powell were periodically entrained and survived passage through the dam; however, water temperatures within the Glen Canyon reach were generally cold enough to impede growth and cease reproduction. In 2022, water temperatures within the Glen Canyon reach were the highest on record, which led to higher survival of entrained warmwater and cool-water fish through the dam (Rogowski and Boyer 2023). There is concern that as Lake Powell continues to decline and warm water is subsequently discharged, coupled with low dissolved oxygen, there will be an increase in warmwater fish, successful recruitment of the highly invasive smallmouth bass, and a decrease in rainbow trout (Rogowski and Boyer 2023).

The Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement (2024 LTEMP Final SEIS) was developed to implement water management actions to temporarily control smallmouth bass populations downstream of Glen Canyon Dam from 2024 to 2027 (Reclamation 2024). The Bureau of Reclamation (Reclamation) is planning to continue coordination with stakeholders for future control of smallmouth bass populations. **TA 8**, Biological Resources – Fish and Other Aquatic Resources, provides further information on rainbow trout dynamics in the Glen Canyon reach.

Lake Mead and Hoover Dam

Lake Mead has an excellent warmwater sportfishery composed of largemouth bass, striped bass, channel catfish, rainbow trout, bullhead catfish, sunfish, crappie, and bluegill. Fishing is generally better in September, October, and November. Larger fish are caught by deepwater trolling in spring from March through May.

The Lake Mead Fish Hatchery, operated by the Nevada Department of Wildlife, historically raised rainbow trout, endangered razorback suckers, and bonytail chub. The Lake Mead Fish Hatchery ceased operations in 2022 in response to Lake Mead declining below 1,060 feet, the point at which the hatchery drew its water (Peterson 2022). The Nevada Department of Wildlife and the Southern Nevada Water Authority are currently developing a project to replace the hatchery's water supply line to draw deeper in the water column.

Hoover Dam to Davis Dam

Lake Mohave's fishery is similar to Lake Mead's fishery. In Lake Mohave, there are largemouth bass, striped bass, channel catfish, rainbow trout, bullhead catfish, sunfish, crappie, and bluegill. Largemouth and striped bass are in deep water in the winter and move into shallow water to spawn in the spring. Fishing is open year-round, but the best fishing generally occurs in September, October, and November. For deepwater trolling, March through May tends to provide the best conditions.

Davis Dam to Parker Dam

Striped bass is the dominant sportfish in Lake Havasu. It can be caught throughout the year, but the best fishing locations change with the seasons and water temperature. The largemouth bass population supports tournaments nearly every weekend from September through May. The smallmouth bass population has increased in number over the past couple of years. Channel catfish are abundant and average 2 to 4 pounds in size. Flathead catfish grow to large sizes in Lake Havasu. Only a limited number of anglers fish specifically for catfish. Black crappie numbers are limited due to overharvesting and a lack of habitat.

Parker Dam to SIB

Fishing in Cibola NWR is available in Pretty Water, Cibola Lake, the Colorado River, and the old river channel. Cibola NWR is managed to protect wintering waterfowl that use Cibola Lake. Fishing is permitted March 15–October 1, unless otherwise stated. Sportfishing in Cibola Lake includes largemouth, smallmouth, and striped bass; channel and flathead catfish; crappie; sunfish; tilapia; and common carp.

Imperial NWR is managed as a refuge and breeding area for migratory birds and other wildlife. Hunting and fishing are permitted in some areas, according to state regulations, and fishing by boat is allowed on the mainstream Colorado River at any time of the year.

TA 14.2 Environmental Consequences

TA 14.2.1 Methodology

Reclamation used similar methods for the analysis of potential impacts on recreation as were used in the 2007 Final EIS and 2024 LTEMP Final SEIS to assess the effects on shoreline public use facilities, reservoir boating and navigational hazards, whitewater boating, and sportfishing. This analysis also incorporates additional Decision Making under Deep Uncertainty (DMDU) concepts, specifically robustness heat maps and vulnerability bar plots, developed to provide an indicator of an alternative's performance across many possible hydrologic futures. Refer to **TA 3**, Hydrologic Resources, and **Section 3.2**, Analysis Methods, for additional information on DMDU. Also, see **Appendix E**, DMDU Overview and Approach, for an overview of interpreting the DMDU robustness heat maps and vulnerability bar plots.

Method Used to Assess Shoreline Public Use Facilities

This section analyzes the impacts that reservoir elevations decreasing below critical thresholds would have on selected marinas, boat docks, and launch ramps, as well as whether these elevations could impact access to or use of attraction features. The NPS provided threshold reservoir elevations included in this analysis. The DMDU analysis uses the subset of reservoir elevations used in the regional economic modeling (see **TA 16**, Socioeconomics). The DMDU analysis for shoreline public use facilities analyzes the percentage of selected marinas, boat docks, and launch ramps. Threshold elevations were used as indicators of recreational facilities that might be rendered inoperable or require relocation or modification to remain operational. The narrative of the alternatives' effects is provided below for selected facilities at both Lake Powell and Lake Mead. These facilities are representative of the alternatives' potential effects on shoreline recreational opportunities at each reservoir.

Method Used to Assess Reservoir Boating and Navigational Hazards

This analysis assesses the effects of reservoir elevations falling below critical thresholds, which would result in boating navigational hazards and changing navigable areas and passageways. This methodology is consistent with the 2007 Final EIS and 2024 LTEMP Final SEIS, but with the addition of new modeling and DMDU concepts, it assesses the percentage of futures in which reservoir elevations never drop below identified thresholds. Threshold pool elevations were determined using the methodology identified in the 2007 Final EIS.

Method Used to Assess Whitewater Boating

The assessment of effects on whitewater boating used a similar methodology identified in the 2007 Final EIS and 2024 LTEMP Final SEIS by using river flow data from **TA 3**, Hydrologic Resources, to analyze whether there would be increased exposures to boating navigational hazards, changes in access or use of rest areas and takeouts, or changes in trip durations resulting from the alternatives. The analysis additionally incorporates DMDU concepts and analyzes the percentage of futures in which daytime flows of the Colorado River would not drop below an identified minimum threshold, previously identified as the minimum preferred flow (Shelby et al. 1992; Stewart et al. 2000).

Methods Used to Assess Sportfishing

This analysis assesses the effects on fishing opportunities by river reach under the alternatives, using similar methods identified in the 2007 Final EIS and 2024 LTEMP Final SEIS. There are no specific reservoir elevation thresholds related to sportfishing; therefore, DMDU concepts are not used in the reservoir sportfishing analysis. A general discussion of changes in flow and salinity, and the possible effects on sportfish is also provided.

A more detailed analysis of effects on rainbow trout based on changes in water temperature is used for the Lees Ferry reach of the Colorado River, which incorporates DMDU concepts. Rainbow trout were chosen for the analysis based on the importance of their recreational fishery in the Colorado River reach below Glen Canyon Dam.

TA 14.2.2 Impact Analysis Area

The impact analysis area for recreation aligns with the general analysis area, which encompasses the Colorado River corridor from the full pool elevation of Lake Powell to the SIB. Flows below Hoover Dam are consistently low due to upstream diversions and delivery obligations. As a result, the range of operational changes evaluated across the alternatives would not meaningfully alter flow conditions in a manner that would measurably affect recreational opportunities in this reach. Given the limited variability in flows and the constrained nature of water-based recreation downstream of Parker Dam, a detailed analysis was determined to be unwarranted. Potential effects in this area would be negligible and would not differ substantially among the alternatives.

Assumptions

- The analysis assumes that the demand for recreational opportunities will either remain constant or increase over time, forming the basis for evaluating impacts on activities such as reservoir recreation, fishing, and whitewater boating.
- The analysis considers 5,000 cfs and 8,000 cfs as two levels at which commercial and private boaters may experience navigability challenges (Bishop et al. 1987; Shelby et al. 1992; Stewart et al. 2000).
- While high-flow experiments are not directly incorporated into the recreation modeling, actual high-flow experiment frequency may differ from that assumed or predicted in other modeling efforts.
- Additional assumptions related to modeling are considered in the analysis, contributing to the accuracy and reliability of the hydrologic models used to anticipate impacts resulting from various actions.

Impact Indicators

- Threshold reservoir elevations
- Threshold river flows
- Water temperatures

TA 14.2.3 Issue 1: How would the management of reservoir elevations affect recreation?

This issue examines how different reservoir elevations (Lake Powell and Lake Mead) resulting from different operational strategies would impact shoreline recreational facilities, reservoir boating activities, sportfishing opportunities, and the ferry and taxi boat services at Lake Powell. This analysis first presents and analyzes DMDU figures, and then assesses qualitative impacts on selected recreation activities resulting from changes in reservoir elevations.

Lake Powell

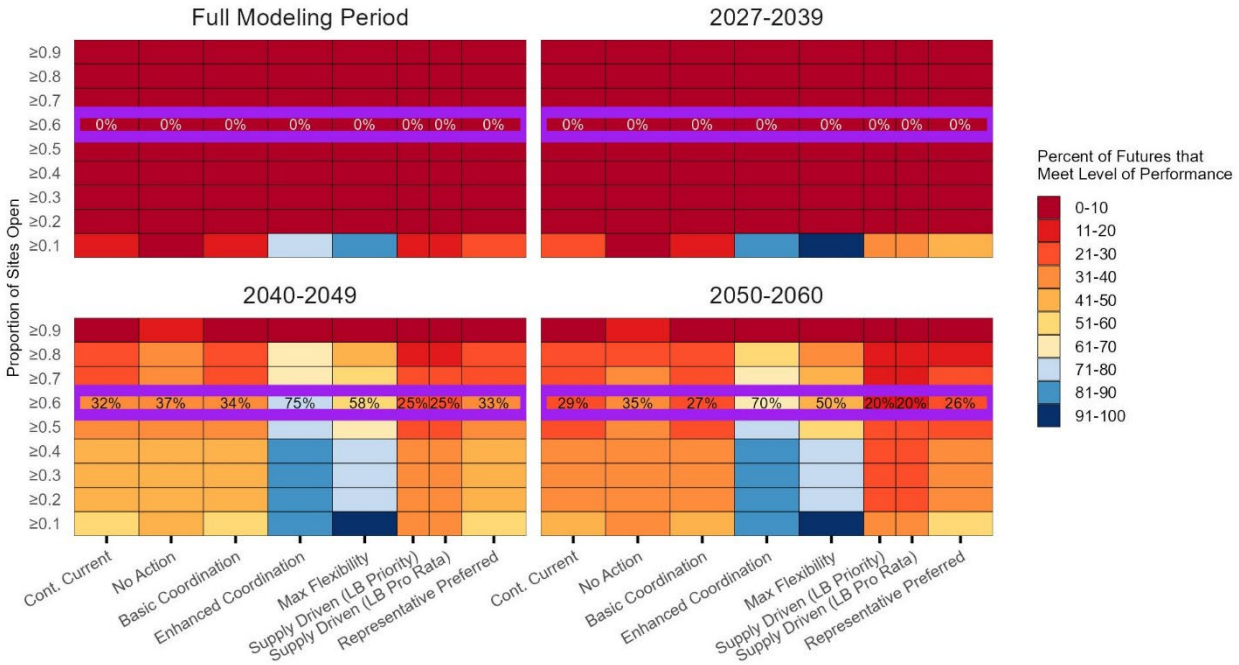
Table TA 14-3 identifies the threshold elevations, or preferred minimum performance levels, below which shoreline recreational facilities at Lake Powell could be affected. Below these elevations, facility adjustments or capital improvements would be required, creating potential impacts on recreation at Lake Powell. The analysis first examines the proportion of Lake Powell recreation sites that would remain open every summer month, then analyzes the performance of alternatives in maintaining Lake Powell elevations above 3,620 feet, which corresponds to the elevation required for safely navigating the Castle Rock Cut; 3,590 feet, the critical threshold for most boat launch facilities; 3,525 feet, below which nearly all current boat ramps would become inaccessible; and 3,500 feet, the critical threshold for planned boat ramp extensions to date.

Figure TA 14-1 below depicts the performance of each alternative with regard to keeping a specified proportion of Lake Powell recreational sites open over every summer month, which corresponds to peak visitation (May 31 – August 31). The figure is divided into four robustness heat maps, each showing a different time period across the analysis. The highlighted row represents the percentage of futures that an alternative achieves maintaining a 0.6 proportion of Lake Powell recreational sites open between May 31 and August 31. The 0.6 proportion row was chosen to be highlighted because it corresponds to approximately the 10th percentile from the historical analysis that informed the thresholds.

Across the full modeling period and the 2027–2039 subperiod, none of the alternatives would maintain keeping at least 60 percent of Lake Powell recreational sites open during the summer months. This indicates that reservoir elevations sufficient to sustain broad recreational site accessibility are unlikely under near-term conditions. Given the planned length of this decision, it is notable that the Representative Preferred Alternative does not meet the preferred minimum performance across the full modeling period or 2027–2039 subperiod, achieving it in only 30 percent of modeled futures in the 2040–2049 subperiod, and 22 percent of modeled futures in the 2050–2060 subperiod.

These results translate to widespread closures of Lake Powell recreation sites and boat launch ramps over the next decade. As access becomes increasingly constrained, use would be concentrated at the remaining operable locations, resulting in longer wait times, limited parking available, and increased congestion at boat ramps and associated facilities. These conditions would reduce the reliability and overall quality of recreation opportunities and may displace some users entirely.

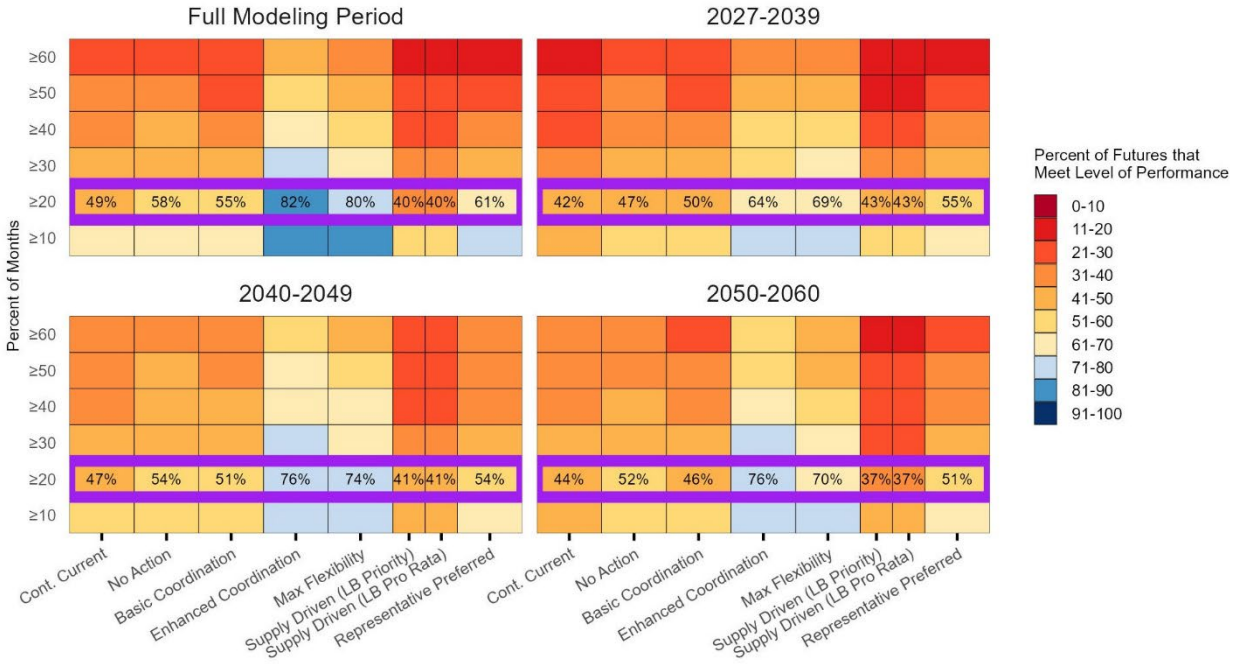
Figure TA 14-1
Lake Powell Recreation Sites: Robustness.
Percent of futures in which the proportion of open Lake Powell sites stays above the value specified by each row in every summer month (May 31 – August 31)



In the later subperiods (2040-2049 and 2050-2060), all alternatives show improved performance in maintaining the 60 percent threshold. This is likely attributed to the preferred standard being easier to meet over shorter timespans than over the full 34 years, and also because these subperiods are further removed from the present dry initial conditions. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at meeting the preferred minimum performance, doing so in 75 percent and 58 percent of futures, respectively, in 2040-2049, and 70 percent and 50 percent of futures, respectively, in 2050-2060. This is considerably more robust than the other alternatives. While these alternatives demonstrate comparatively greater robustness, even their improved performance does not eliminate the risk of access limitations and associated declines in reservoir boating experience under lower reservoir elevations.

Figure TA 14-2 below depicts the performance of each alternative with regard to maintaining Lake Powell above an elevation of 3,620 feet, which corresponds to the elevation required for safely navigating the Castle Rock Cut. The figure is divided into four heat maps, each showing a different time period across the analysis. Rows of the heat map show different frequency ranges (percent of months) for keeping Lake Powell above an elevation of 3,620 feet. The highlighted row shows the percentage of futures that an alternative achieves in maintaining Lake Powell above this elevation in 20 percent or more of months. This row was chosen to be highlighted because, from October 2007 through May 2025, Lake Powell was at or above 3,620 feet in 24.5 percent of months.

Figure TA 14-2
Lake Powell Boating Hazards: Robustness.
Percent of futures in which the elevation of Lake Powell is at least 3,620 feet in the percent of months specified by each row



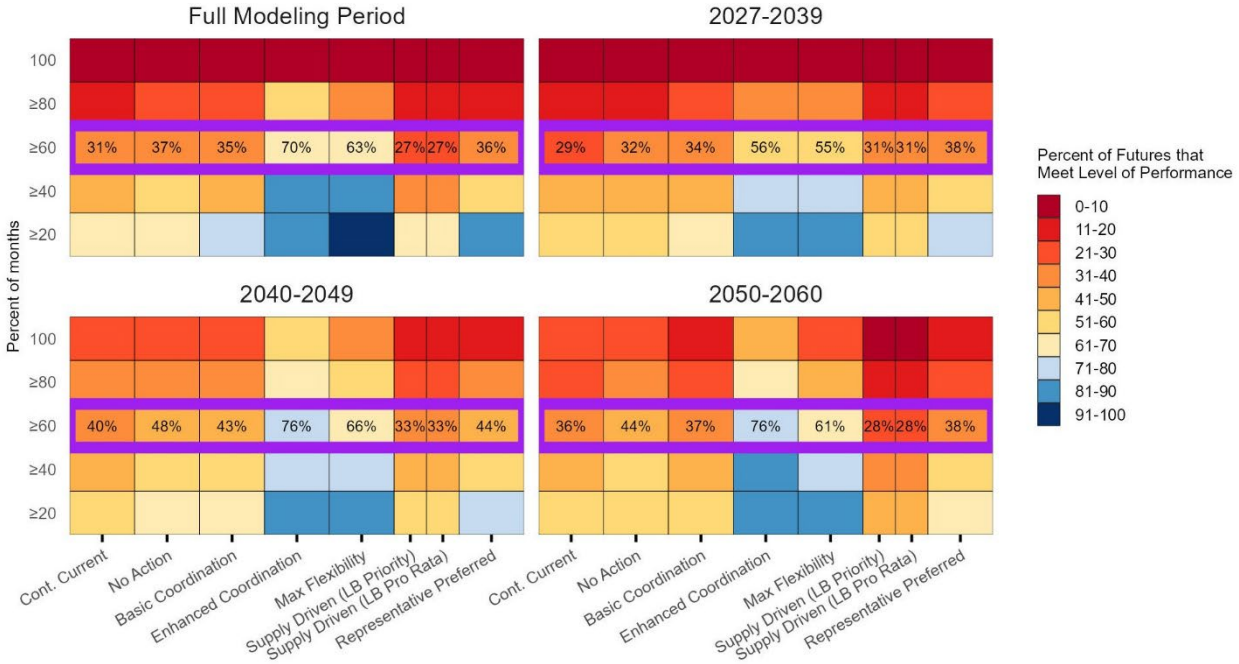
The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at maintaining or exceeding a Lake Powell elevation of 3,620 feet in 20 percent or more of months over the full modeling period, as shown in the upper-left heat map. These alternatives perform similarly to one another, doing so in 82 percent and 80 percent of futures, respectively. Over the full modeling period, the Basic Coordination, No Action, and Representative Preferred Alternatives perform similarly, succeeding in 55 percent, 58 percent, and 61 percent of futures, respectively. These alternatives are slightly more robust than the Continued Current Strategies (CCS) Comparative Baseline and the Supply Driven Alternative (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches), which only meet the preferred minimum performance in 49 percent and 40 percent of futures across the full modeling period, respectively.

Across the full modeling period, all alternatives exhibit poor performance for the upper rows. Under all alternatives, projected Lake Powell elevations for much of the analysis period would be below the critical threshold for safely navigating the Castle Rock Cut. This would result in a reduction in the quality of or the loss of reservoir boating opportunities on Lake Powell. Under all alternatives, dock access would continue to be unavailable from the Rainbow Bridge National Monument shoreline, which would continue until a long-term access solution is developed. Similarly, under all alternatives, projected Lake Powell elevations for much of the analysis period would be below the critical threshold for the Charles Hall Ferry, which would therefore be unable to operate.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance level in 82 and 80 percent of futures, respectively. The No Action, Basic Coordination, and Representative Preferred Alternatives perform similarly, meeting the preferred minimum performance level in 55 to 61 percent of futures. The CCS Comparative Baseline and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are less robust, meeting the preferred minimum performance level in 49 and 40 percent of futures, respectively.

Figure TA 14-3 below depicts the performance of each alternative with regard to maintaining Lake Powell above an elevation of 3,590 feet, which corresponds to the critical threshold for most boat launch facilities. The figure is divided into four heat maps, each showing a different time period across the analysis. Rows of the heat map show different frequency ranges (percent of months) for keeping Lake Powell above an elevation of 3,590 feet. The highlighted row shows the percentage of futures that an alternative achieves in maintaining Lake Powell above this elevation in 60 percent or more of months. This row was chosen to be highlighted because it corresponds to approximately the 10th percentile from the historical analysis.

Figure TA 14-3
Lake Powell Boat Ramps 3,590 Feet: Robustness.
Percent of futures in which Lake Powell elevation is 3,590 feet or greater in the specified percent of months



The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at maintaining or exceeding a Lake Powell elevation of 3,590 feet in 60 percent or more of months over the full modeling period, as shown in the upper-left heat map. These alternatives perform

similarly to one another, succeeding in 70 percent and 63 percent of futures, respectively. Over the full modeling period, the CCS Comparative Baseline, No Action, Basic Coordination, and Representative Preferred Alternatives perform similarly, succeeding in 31 percent, 37 percent, 35 percent, and 36 percent, respectively. These alternatives are slightly more robust than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), which only meet the preferred minimum performance in 27 percent of futures.

Across the full modeling period, all alternatives exhibit poor performance for the upper rows. This suggests that challenges related to accessing existing Lake Powell boat ramps and associated impacts described above will continue under all alternatives.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust, meeting the preferred minimum performance level in 56 and 55 percent of futures, respectively, followed by the Representative Preferred Alternative at 38 percent. The No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives perform similarly, meeting the preferred minimum performance level between 31 and 34 percent of futures. The CCS Comparative Baseline is least robust, meeting the preferred minimum performance level in 29 percent of futures.

Figure TA 3-9 in **TA 3,** Hydrologic Resources, compares alternatives with respect to maintaining Lake Powell above an elevation of 3,525 feet. This elevation is important to recreation because it corresponds to the threshold that nearly all existing boat ramps become inaccessible. The purple highlighted row shows the percentage of futures that an alternative maintains Lake Powell above 3,525 feet in at least 90 percent of months. Please refer to this figure in **TA 3**, Hydrologic Resources.

In the Full Modeling Period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred minimum level of performance in 80 percent and 72 percent of the modeled futures, respectively, which is considerably more robust than the other alternatives. The CCS Comparative Baseline and No Action Alternative are only able to meet the preferred minimum performance in 29 percent and 24 percent of futures, respectively. The Representative Preferred Alternative meets the preferred level of performance in 50 percent of modeled futures in the Full Modeling Period. For the more stringent performance standard of keeping Lake Powell above 3,525 feet in 100 percent of months, all alternatives and the CCS Comparative Baseline show poor levels of performance and can only meet the more stringent standard in 0-10 percent of futures.

Based on the planned length of this decision it is important to note that in the first subperiod (2027–2039) the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 72 percent and 64 percent of futures respectively. The CCS Comparative Baseline and Basic Coordination and Supply Driven (both LB Priority and Pro Rata approaches) Alternatives are similarly less robust meeting the preferred minimum performance in 34 percent, 38 percent, and 36 percent of futures respectively. The No Action Alternative is least robust meeting the preferred minimum performance in only 25 percent of futures in the first subperiod.

The Representative Preferred Alternative meets the preferred minimum performance level in 52 percent of futures in the first modeling period (2027–2039).

The alternatives meet the preferred minimum level of performance in greater percentages of futures in subperiods than the Full Modeling Period because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state (2027 begins with relatively low reservoir elevations) cause worse performance in the first decade than the following two decades. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the Full Modeling Period.

With respect to lower rows in the heatmap, which reflect lower percentages of years where Lake Powell elevation is above 3,525 feet, all alternatives improve.

Figure TA 3-7 in **TA 3,** Hydrologic Resources, compares alternatives with respect to maintaining Lake Powell above an elevation of 3,500 feet. This elevation is important to recreation because it corresponds to the threshold that nearly all planned extensions to boat ramps would become inaccessible. The purple highlighted row shows the percentage of futures that an alternative maintains Lake Powell above 3,500 feet in 100 percent of months. This was chosen as the preferred minimum performance level due to the importance of avoiding critical impacts on water deliveries and hydropower, which, although not directly related to recreation, also aligns with a key recreational infrastructure threshold. Please refer to this figure in **TA 3**, Hydrologic Resources.

In the Full Modeling Period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives can meet the preferred level of performance in 74 percent and 86 percent of the modeled futures, respectively, which is considerably more robust than the other alternatives. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are the least robust and are only able to meet the preferred minimum performance in 18 percent, 4 percent, 13 percent, and 18 percent of futures, respectively.

Based on the planned length of this decision, it is important to note that in the first modeling period (2027–2039) the Enhanced Coordination and Maximum Operational Flexibility Alternatives are most robust, achieving the preferred minimum level of performance in 81 percent and 94 percent of futures respectively. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative and the CCS Comparative Baseline are less robust meeting the preferred minimum performance in 35 percent and 30 percent of futures respectively. The No Action and Basic Coordination Alternatives are least robust in the first modeling period meeting the preferred minimum performance in only 4 percent and 19 percent of futures respectively.

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state (2027 begins with relatively low reservoir elevations) cause worse performance in the first decade.

In the lower rows of the heat maps, which reflect lower percentages of months where Lake Powell elevation stays above 3,500 feet, all alternatives improve.

The Representative Preferred Alternative meets preferred level of performance in 40 percent of modeled futures in the Full Modeling Period. Based on the planned length of this decision, it is

important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 58 percent of futures in the first modeling period (2027–2039).

These results indicate a substantial risk that reservoir elevations would drop below the thresholds required for the planned boat ramp extensions to function, particularly over the next decade. This suggests that even with planned infrastructure improvements, access could remain constrained or, in some cases, unavailable without additional modifications to support operations at elevations below 3,500 feet. As a result, Lake Powell reservoir boating access may be intermittent and concentrated at a limited number of locations.

Sportfishing

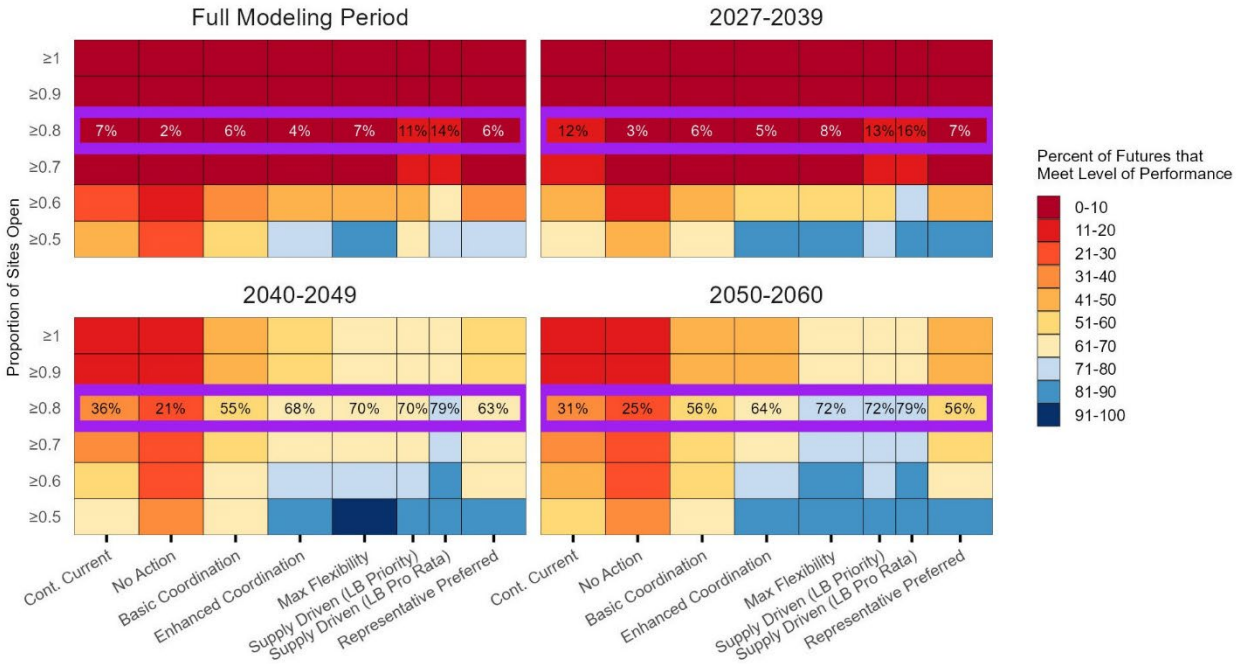
There are no specific reservoir elevation thresholds or river stages related to sportfishing identified from the literature reviewed. Catch rates for reservoir fishing are assumed to be directly related to reservoir habitat. Generally, lower reservoir elevation also reduces lake habitat for sportfish, which may have a negative impact on recreational sportfishing. Higher lake levels tend to favor popular sportfish, like largemouth bass, bluegill, and crappie, whereas lower levels favor smallmouth bass (Gustaveson 2018). The general trend for the alternatives indicates that the Maximum Operational Flexibility and Enhanced Coordination Alternatives have higher, less variable results centered around 3,600 feet, while the Supply Driven (both LB Priority and LB Pro Rata approaches), Basic Coordination, No Action, and Representative Preferred Alternatives, and the CCS Comparative Baseline, have median elevations around 3,560 feet. Therefore, the Maximum Operational Flexibility and Enhanced Coordination Alternatives would likely be more beneficial for reservoir sportfishing.

Lake Mead

Table TA 14-6 identifies the threshold elevations below which shoreline recreational facilities at Lake Mead could be affected. Below these elevations, facility adjustments or capital improvements would be required, potentially impacting recreation at Lake Mead. The analysis first examines the proportion of Lake Mead recreation sites that would remain open every summer month, then analyzes the performance of alternatives in maintaining Lake Powell elevations above 1,170 feet, which corresponds to the elevation required for avoiding most navigational hazards; 1,040 feet, the historic low elevation; and 1,000 feet, the elevation at which all existing boat ramp access would be lost.

Figure TA 14-4 below depicts the performance of each alternative with regard to keeping a specified proportion of Lake Mead recreational sites open over every summer month, which corresponds to peak visitation (May 31 – August 31). The figure is divided into four heat maps, each showing a different time period across the analysis. The highlighted row shows the percentage of futures in which an alternative achieves maintaining a 0.8 proportion of Lake Mead recreational sites open between May 31 and August 31. The 0.8 proportion row was highlighted because it corresponds to approximately the 10th percentile from the historical analysis that informed the thresholds.

Figure TA 14-4
Lake Mead Recreation Sites: Robustness.
Percent of futures in which the proportion of open Lake Mead sites stays above the value specified by each row in every summer month (May 31 – August 31)



Note: Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

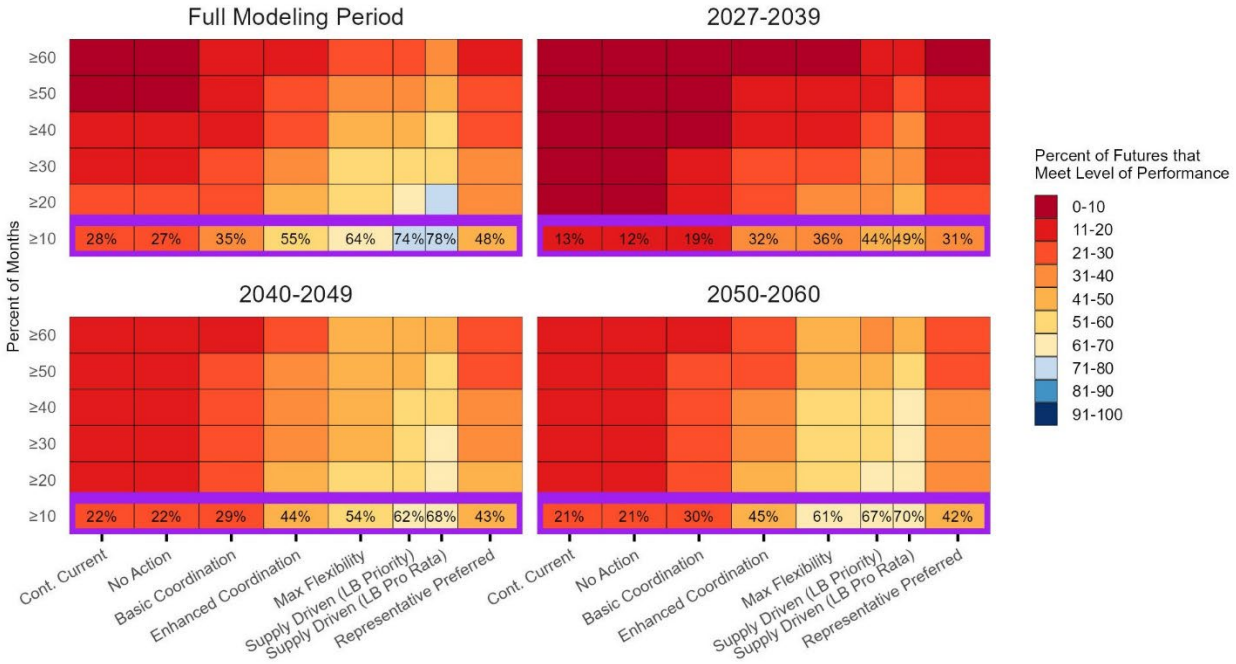
Across the full modeling period, all alternatives exhibit poor performance at maintaining at least 80 percent of Lake Mead recreational sites open during the summer months, indicating that widespread reductions in recreation site availability are likely under a broad range of future conditions. The Supply Driven Alternative (LB Pro Rata approach) is the most robust at achieving the preferred minimum level of performance over the full modeling period but still does so in only 14 percent of modeled futures. The Supply Driven (LB Priority approach) performs similarly, succeeding in 11 percent of futures. All other alternatives perform at or below these levels. The Maximum Operational Flexibility Alternative and CCS Comparative Baseline perform the same over the full modeling period, succeeding in 7 percent of modeled futures, while the Basic Coordination, Representative Preferred, Enhanced Coordination, and No Action Alternatives succeed in only 6 percent, 6 percent, 4 percent, and 2 percent of futures, respectively, over the full modeling period.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The CCS Comparative Baseline and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative are most robust, meeting the preferred minimum performance level between 12 and 16 percent of futures. The Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, and the Representative Preferred Alternatives meet the preferred

minimum performance level in 6 percent, 5 percent, 8 percent, and 7 percent of futures, respectively. The No Action Alternative is least robust, meeting the preferred minimum performance level in 3 percent of futures. These results indicate that reduced access to Lake Mead recreation sites is likely to persist over the next decade. As site availability declines, use would be concentrated at fewer locations, contributing to increased congestion, limited parking, and reduced reliability of recreation opportunities.

Figure TA 14-5 depicts the performance of each alternative with regard to the percent of futures in which the Lake Mead elevation is 1,170 feet or above in the specified minimum percent of months across the full modeling period (2027–2060) and three subperiods. Rows of the heat map show different frequency ranges for keeping Lake Mead above this elevation for a specified percentage of months throughout the full modeling period. Lake Mead has not been at or above an elevation of 1,170 feet between October 2007 and May 2025; therefore, the 10 percent row was chosen to be highlighted.

Figure TA 14-5
Lake Mead Boating Hazards: Robustness.
Percent of futures in which the elevation of Lake Mead is at least 1,170 feet in the percent of months specified by each row



Note: Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust at maintaining or exceeding a Lake Mead elevation of 1,170 feet in 10 percent or more of months over

the full modeling period, as shown in the upper-left heat map. The LB Pro Rata and LB Priority approaches perform similarly to one another, doing so in 78 percent and 74 percent of futures, respectively. Over the full modeling period, performance is followed by the Maximum Operational Flexibility Alternative, the Enhanced Coordination Alternative, and the Representative Preferred Alternative, which succeed in 64 percent, 55 percent, and 48 percent of futures, respectively. The Basic Coordination Alternative, CCS Comparative Baseline, and No Action Alternative are the least robust at achieving the minimum level of performance, succeeding in 35 percent, 28 percent, and 27 of modeled futures, respectively.

Across the full modeling period, all alternatives exhibit poor performance in the upper rows. The analysis suggests that it is difficult to achieve a Lake Mead elevation above which boating navigational hazards would not occur.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is most robust, meeting the preferred minimum performance level in 44 percent (LB Priority approach) to 49 percent (LB Pro Rata approach) of futures. The Maximum Operational Flexibility Alternative meets the preferred minimum performance level in 36 percent of futures, followed closely by the Enhanced Coordination Alternative (32 percent) and Representative Preferred Alternative (31 percent). The CCS Comparative Baseline and the No Action and Basic Coordination Alternatives are less robust, meeting the preferred minimum performance level in 13, 12, and 19 percent of futures, respectively.

Figure TA 14-6 below depicts the performance of each alternative with regard to the percent of futures in which the Lake Mead elevation is 1,040 feet or above in the specified minimum percent of months across the full modeling period (2027–2060) and three subperiods. This elevation corresponds to the historical low Lake Mead elevation. Rows of the heat map show different frequency ranges for keeping Lake Mead above this elevation for a specified percentage of months throughout the full modeling period. The purple highlighted row shows the percentage of futures that an alternative maintains Lake Mead at or above 1,040 feet in at least 90 percent of months. This row was chosen to be highlighted because it corresponds to approximately the 10th percentile from the historical analysis.

The Supply Driven Alternative (LB Pro Rata approach) is the most robust at maintaining or exceeding a Lake Mead elevation of 1,040 feet in 90 percent or more of months over the full modeling period, doing so in 51 percent of futures. Over the full modeling period, performance is followed by the Enhanced Coordination, Supply Driven (LB Priority approach), Maximum Operational Flexibility, and Representative Preferred Alternatives, which succeed in 42 percent, 39 percent, 33 percent, and 27 percent of modeled futures, respectively. The Basic Coordination Alternative, CCS Comparative Baseline, and No Action Alternative exhibit the worst performance, succeeding in 22 percent, 16 percent, and 8 percent of modeled futures, respectively.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust, meeting the preferred minimum performance level in 22 percent

(LB Priority approach) to 28 percent (LB Pro Rata approach) of futures. The Maximum Operational Flexibility and Representative Preferred Alternatives both meet the preferred minimum performance level in 18 percent of futures, followed by the CCS Comparative Baseline (17 percent), Enhanced Coordination Alternative (16 percent), and Basic Coordination Alternative (12 percent). The No Action Alternative is least robust, meeting the preferred minimum performance level in 5 percent of futures. These results indicate a high likelihood that Lake Mead levels would fall below the historic low elevation over the next decade. Such conditions would constrain access at existing boat ramps, particularly those already operating near minimum functional elevations, potentially rendering some facilities inoperable. As access becomes more limited, this would result in impacts previously described above.

Figure TA 14-6
Lake Mead Boat Ramps: Robustness.
Percent of futures in which Lake Mead elevation is 1,040 feet or greater in the specified percent of months

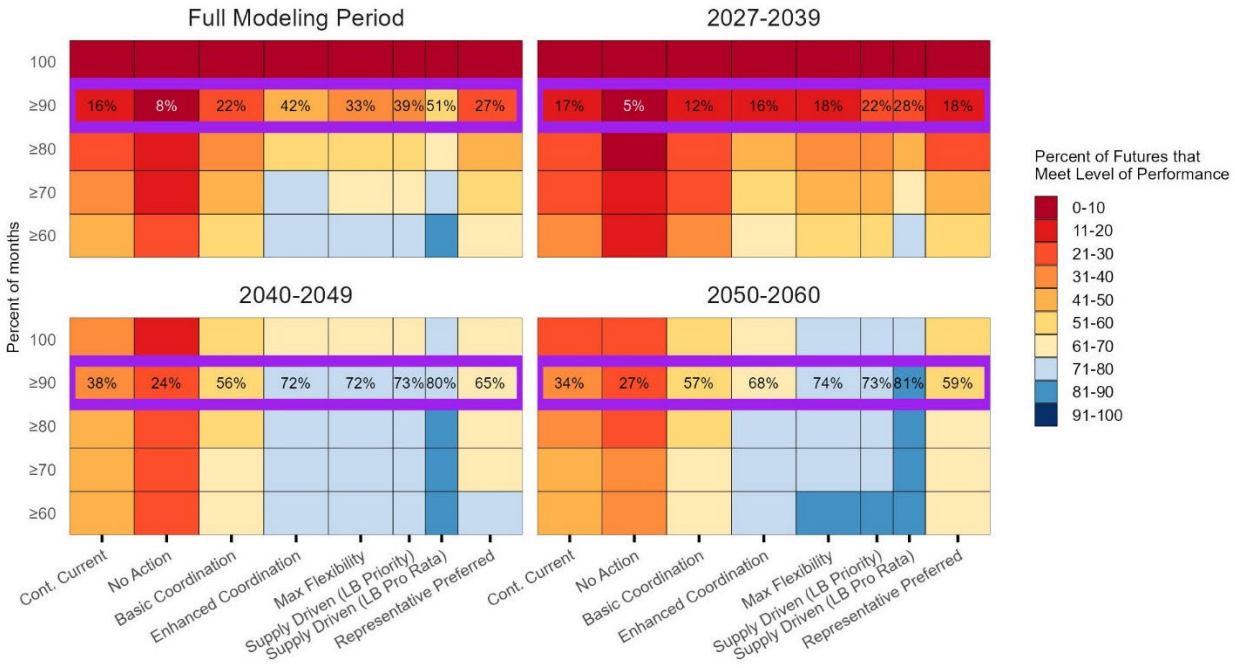


Figure TA 3-14 in **TA 3**, Hydrologic Resources, compares alternatives with respect to maintaining Lake Mead above an elevation of 1,000 feet. This elevation is important to recreation because it corresponds to the threshold that nearly all boat ramps would become inaccessible. The purple highlighted row shows the percentage of futures that an alternative maintains Lake Mead above 1,000 feet in 90 percent of months. Please refer to this figure and rationale for selection of this threshold as the preferred minimum level of performance in **TA 3**, Hydrologic Resources.

In the Full Modeling Period, the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives are similarly robust, meeting the preferred minimum level of performance in 71 percent, 71 percent, 64 percent,

and 74 percent of futures, respectively. The CCS Comparative Baseline and No Action Alternative are the least robust, meeting the preferred minimum performance in 46 percent and 20 percent of futures, respectively.

Based on the planned length of decision, it is important to note that in the first decade (2027–2039) Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives are similarly robust, meeting the preferred minimum level of performance in 70 percent, 67 percent, 64 percent, and 77 percent of futures respectively. The CCS Comparative Baseline and Basic Coordination Alternatives are somewhat less robust, meeting the preferred minimum performance in 54 percent and 55 percent of futures respectively. In the first modeling period, the No Action Alternative is the least robust, meeting the preferred minimum performance in 25 percent of modeled futures.

The Representative Preferred Alternative meets the preferred minimum level of performance in 63 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to note that the Representative Preferred Alternative meets the preferred minimum performance level in 62 percent of futures in the first modeling period (2027–2039).

In the three subperiods, the alternatives meet the preferred minimum level of performance in greater percentages of futures because the preferred standard is easier to meet over shorter timespans than over the full 34 years. Additionally, the observed data prior to modeling and the initial system state (2027 begins with relatively low reservoir elevations) cause worse performance in the first decade. The robustness ranking across the three alternatives in each subperiod is consistent with the ranking in the Full Modeling Period.

In the remaining modeled futures in which minimum performance is not achieved, reservoir elevations would fall below the levels required to sustain boat ramp operations, resulting in a complete loss of reservoir boating opportunities at Lake Mead. Such conditions would eliminate launching opportunities until water levels recover or additional infrastructure modifications are implemented, substantially constraining recreation access and use.

TA 14.2.4 Issue 2: How would the management of releases from Glen Canyon Dam affect recreation, including water temperature?

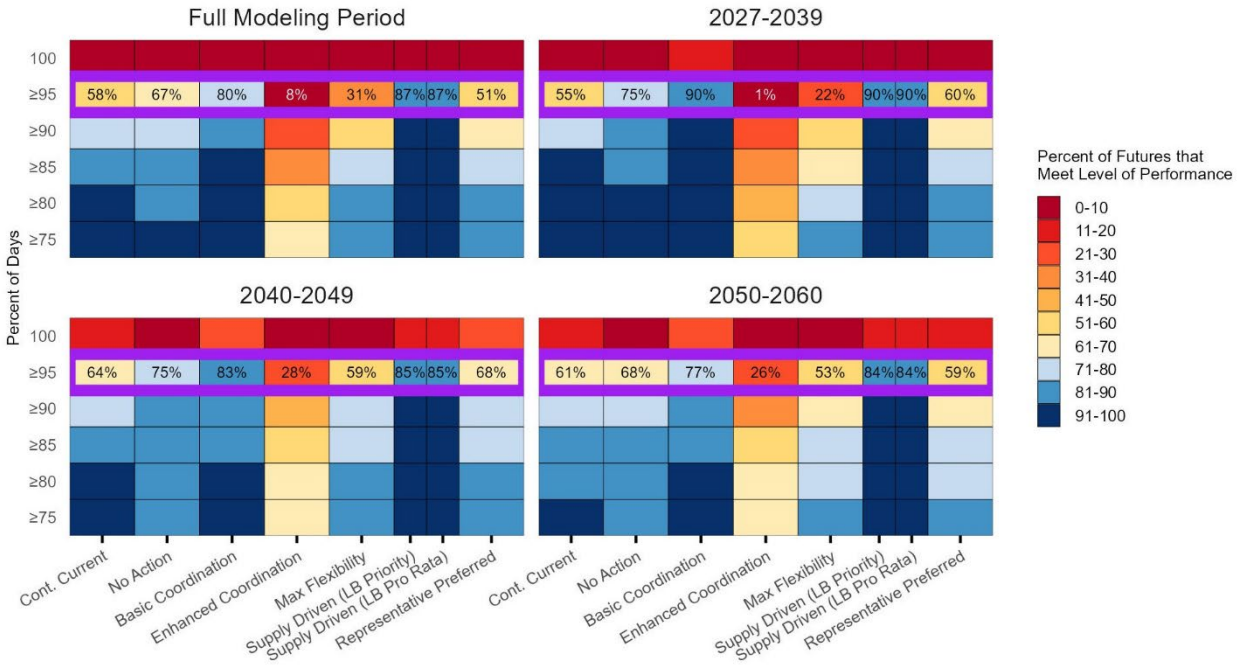
Whitewater Boating

River flow levels and fluctuations are important for whitewater boaters. The minimum daily flow levels of 8,000 cfs were set under the 2016 Glen Canyon Dam Long-Term Experimental and Management Plan Final EIS as the minimally adequate daytime levels for Grand Canyon boating. Levels lower than this may present increasing navigability challenges for the use of large (often 35 feet long) rafts equipped with motors. Extended low flows of 5,000 cfs would adversely affect navigability and trip management because of a greater risk of boating incidents. Commercial and private whitewater trip leaders have reported a preference for steady flows (flows that do not fluctuate by more than 10,000 cfs per day) in the 20,000-26,000 cfs range (Bishop et al. 1987; Neher et al. 2017); thus, there would likely be greater perceived value to rafters when flows are within this range. However, the historical and projected volume range under the alternatives may not align with

these preferences, and the exact impacts on recreation would continue to depend on water availability for releases.

Figure TA 14-7 depicts the performance of each alternative with regard to the percent of futures in which daytime flows (7 a.m. – 7 p.m.) below Glen Canyon Dam are at least 8,000 cfs in the specified percent of days over the full modeling period (2027–2060) and three subperiods. Rows of the heat map show different frequency ranges for keeping daytime flows above this threshold in the specified percentage of days throughout the full modeling period.

Figure TA 14-7
Whitewater Boating Below Glen Canyon Dam, 8,000 cfs: Robustness. Percent of futures in which daytime flows below Glen Canyon Dam are greater than or equal to 8,000 cfs in the percent of days specified by each row



The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust at maintaining or exceeding daytime flows of 8,000 cfs below Glen Canyon Dam over the full modeling period, as shown in the upper-left heat map; succeeding in 87 percent of futures. The Basic Coordination Alternative achieves a similar robustness of 80 percent. Over the full modeling period, performance is followed by the No Action Alternative, which would succeed in 67 percent of futures, and the CCS Comparative Baseline, which would succeed in 58 percent of futures. The Representative Preferred Alternative would succeed in 51 percent of futures. The Maximum Operational Flexibility Alternative would succeed in 31 percent of futures, and the Enhanced Coordination Alternative would be the least robust, succeeding in only 8 percent of futures.

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Basic

Coordination Alternatives are the most robust, meeting the preferred minimum performance level in 90 percent of futures. The No Action Alternative meets the preferred minimum performance level in 75 percent of futures, and the Representative Preferred Alternative meets this performance level in 60 percent of futures. The CCS Comparative Baseline (55 percent) and Maximum Operational Flexibility Alternative (22 percent) are less robust. The Enhanced Coordination Alternative is least robust, meeting the preferred minimum performance level in 1 percent of futures.

In the remaining modeled futures in which minimum performance is not achieved, daytime flows would fall below the levels required to safely navigate the river for large rafts with motors. Such conditions would eliminate rafting opportunities for large group trips until water levels recover, substantially constraining recreation access and use.

Figure TA 14-8 depicts the performance of each alternative with regard to the percent of futures in which daytime flows (7 a.m. – 7 p.m.) below Glen Canyon Dam are at least 5,000 cfs in the specified percent of days over the full modeling period (2027–2060) and three subperiods. Rows of the heat map show different frequency ranges for keeping daytime flows above this threshold in the specified percentage of days throughout the full modeling period.

The Supply Driven (both LB Priority and LB Pro Rata approaches) and Enhanced Coordination Alternatives are the most robust at maintaining or exceeding daytime flows of 5,000 cfs below Glen Canyon Dam over the full modeling period, as shown in the upper-left heat map. These alternatives would succeed in 97 percent and 98 percent of futures, respectively. The Representative Preferred Alternative would succeed in 92 percent of futures. The CCS Comparative Baseline would succeed in 80 percent of futures across the full modeling period, followed by the Basic Coordination Alternative (79 percent), then the No Action Alternative (76 percent), and finally, the Maximum Operational Flexibility Alternative (33 percent).

Based on the planned length of this decision, it is important to compare robustness in the 2027–2039 modeling period. The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is most robust, meeting the preferred minimum performance level in 100 percent of futures. The CCS Comparative Baseline, Enhanced Coordination Alternative, and Representative Preferred Alternative follow closely, meeting the preferred minimum performance level between 96 and 99 percent of futures. The No Action and Basic Coordination Alternatives are less robust, meeting the preferred minimum performance level in 92 and 94 percent of futures, respectively. The Maximum Operational Flexibility Alternative is least robust, meeting the preferred minimum performance level in 40 percent of futures. When flows are above 5,000 cfs, there would generally be fewer navigation challenges and boating incidents caused by a change in river levels. Minor changes in exposure to boating navigational hazards caused by a change in river velocity; changes in access or use of rest areas and take-out points; changes in trip duration caused by changes in river velocity; or the ability to use sportfishing sites caused by changes in flows, may occur under all alternatives.

Figure TA 14-8
Whitewater Boating Below Glen Canyon Dam, 5,000 cfs: Robustness.
Percent of futures in which daytime flows below Glen Canyon Dam are greater than or equal to 5,000 cfs in the percent of days specified by each row

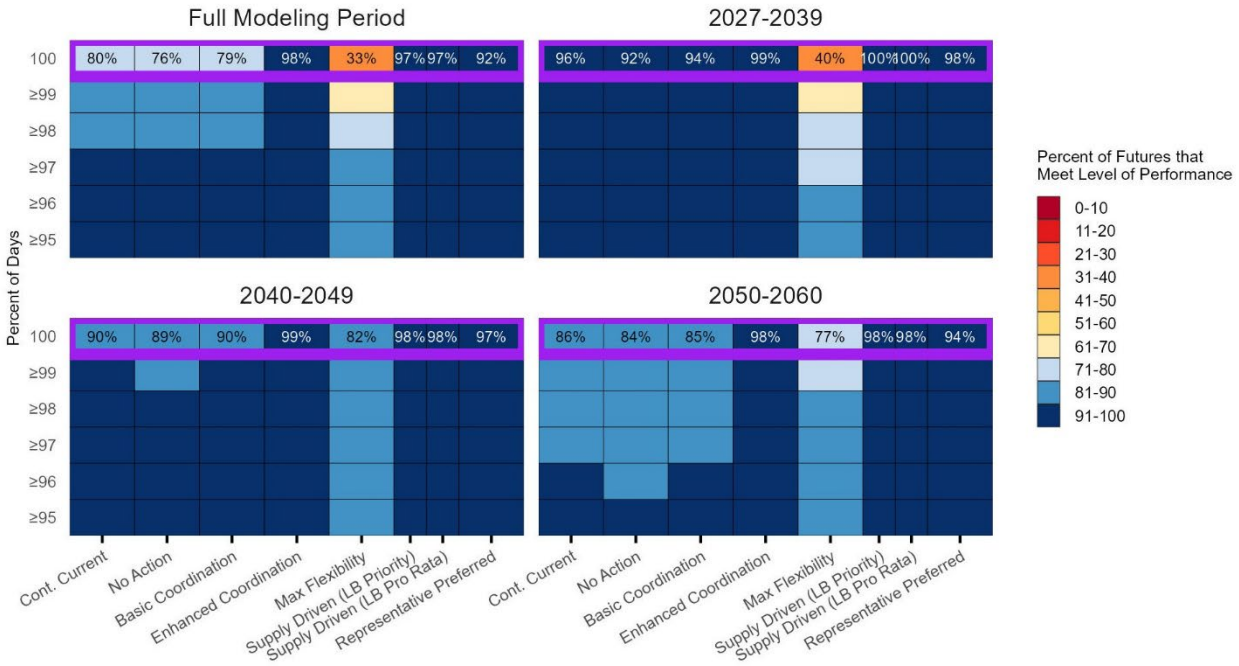


Figure TA 9-11 in **TA 9**, Vegetation Including Special Status Species, depicts arrowweed suitable habitat under each alternative by Grand Canyon sub-reach. Please refer to this figure in **TA 9**, Vegetation Including Special Status Species. Across all three reaches, all alternatives show similar trends. Under the Average Flow Category, the median for each alternative overlaps or nearly overlaps the modeled historic conditions, and the interquartile conditions are relatively small. This suggests that arrowweed suitable habitat may be similar to historic conditions under the Average Flow Category.

Across all three sub-reaches, under the Wet Flow Category and Moderately Wet Flow Category, the median and interquartile ranges are below the modeled historic conditions for all alternatives except for interquartile ranges of the No Action Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) in the Moderately Wet Flow Category. This suggests that there would be less arrowweed suitable habitat under the Wet and Moderately Wet Flow Categories under all sub-reaches and all alternatives. Under the Dry Flow Category, the median and interquartile ranges are above historic conditions (dashed line), for all alternatives except the CCS Comparative Baseline and Enhanced Coordination Alternatives. Under the Critically Dry Flow Category the median and interquartile ranges are above the modeled historic conditions for all sub-reaches and all alternatives except for the CCS Comparative Baseline, although the median remains above historic conditions. This indicates that there may be more arrowweed suitable habitat under Critically Dry Flow Category for all alternatives across all sub-reaches.

These results indicate that in futures with drier flow category conditions, there may be more arrowweed suitable habitat, which would further encroach on available campsite areas within the Grand Canyon compared to under the average or wet flow categories.

Sportfish Populations

While different water temperature thresholds were considered for native and invasive fish species, this section focuses on impacts on the rainbow trout fishery at Lees Ferry. Water temperatures exceeding 20 °C (degrees Celsius; 68 °F [degrees Fahrenheit]) can cause thermal stress and mortality of rainbow trout while creating conditions more favorable for the growth of nonnative fish and smallmouth bass. Additionally, warmer water temperatures may increase the competitive advantage for brown trout, as this species is more tolerant of elevated temperatures. The percentage of futures for each alternative in which water temperature at Lees Ferry exceeds 20 °C (68 °F) is presented in **Figure TA 8-10** under **TA 8**, Biological Resources – Fish and Other Aquatic Resources.

Over the full modeling period, the Enhanced Coordination Alternative is the most robust, meeting the preferred minimum performance level in 56 percent of futures. The Maximum Operational Flexibility Alternative performs lower than the Enhanced Coordination Alternative at 47 percent but still performs substantially better than the remaining alternatives. The No Action Alternative and Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) perform similarly and are the least robust, meeting the preferred minimum performance level in 12 to 18 percent of futures and performing similarly to the CCS Comparative Baseline. Decadal comparisons of robustness reveal similar rankings among the alternatives. Robustness scores tend to be lowest in 2027 due to the low initial reservoir conditions in 2027. Robustness is highest after 2040, with the best-performing alternatives—the Enhanced Coordination Alternative and the Maximum Operational Flexibility Alternative—nearing or exceeding 80 percent in meeting the preferred minimum performance threshold.

The Representative Preferred Alternative meets the preferred minimum performance level robustness criteria in 20 percent of modeled futures in the full modeling period. Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination (62 percent) and Maximum Operational Flexibility (60 percent) Alternatives are the most robust. The remaining action alternatives (including the Representative Preferred Alternative) and the CCS Comparative Baseline are similarly less robust (27-36 percent). The No Action Alternative is the least robust (19 percent).

Alternatives that support higher Lake Powell elevations and greater river flows generally perform better at maintaining cooler water temperatures. However, under extended drought (low average flows and lower Lake Powell elevation), all alternatives become more vulnerable to undesirable temperature increases, affecting fish habitat and species composition. Please refer to **TA 8**, Biological Resources – Fish and Other Aquatic Resources, Issue 2, for more detailed information on changes in water temperature and quality from Glen Canyon Dam downstream through the Grand Canyon to Pearce Ferry and impacts on rainbow trout, native Grand Canyon fishes, and nonnative predatory fish.

TA 14.2.5 Summary Comparison of Alternatives

The alternatives vary in their potential to affect recreational resources, including shoreline public use facilities, reservoir boating, river and whitewater boating, and sportfishing. The general trend for the alternatives indicates that the Maximum Operational Flexibility and Enhanced Coordination Alternatives have higher, less variable Lake Powell reservoir elevations; therefore, these alternatives would likely be more beneficial for all Lake Powell recreational activities. The general trend for the alternatives indicates the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has higher, less variable Lake Mead reservoir elevations, followed by the Maximum Operational Flexibility and Enhanced Coordination Alternatives; therefore, these alternatives would likely be more beneficial for all Lake Mead recreational activities. The Representative Preferred Alternative generally performs in the middle of the range of alternatives for both Lake Powell and Lake Mead elevations, showing moderate robustness but not outperforming the top-performing option.

However, across the full modeling period, all alternatives have poor levels of performance for maintaining higher elevations for a greater percentage of futures. Under all alternatives, projected Lake Powell and Lake Mead elevations for much of the analysis period would be below the critical thresholds for most boat launch facilities and safe boat navigation, which would result in a reduction in the quality of or the loss of reservoir boating opportunities.

Under the Basic Coordination Alternative, projected flows would be the highest in the Critically Dry Flow Category; however, river flows generally decrease as flow categories get drier. Higher flows would generally yield the greatest benefits to whitewater boating in the Grand Canyon. The Enhanced Coordination and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are the most robust at achieving daytime flows of 5,000 cfs or greater, which is above the safe whitewater boating minimum for large, motorized watercraft. Again, the Representative Preferred Alternative generally performs in the middle of the range of alternatives, showing moderate robustness. The Enhanced Coordination Alternative is the most robust at maintaining cooler water temperatures at Lees Ferry, which would confer the greatest benefits to the rainbow trout fishery.

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Technical Appendix 15

Dams and Electrical Power Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
Basin	Colorado River Basin
BCP	Boulder Canyon Project
CCS	Continued Current Strategies
cfs	cubic feet per second
CRiSPPy	Colorado River Storage Project Python-based model
CRSP	Colorado River Storage Project
CRSPA	Colorado River Storage Project Act of 1956
CRSS	Colorado River Simulation System
DMDU	Decision Making under Deep Uncertainty
DSPR	Dam Safety Priority Rating
EIS	environmental impact statement
GWh	gigawatt hour
HFE	high-flow experiment
kW	kilowatt
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
LTEMP	Long-Term Experimental and Management Plan
maf	million acre-feet
MW	megawatts
MWh	megawatt hours
NERC	North American Electric Reliability Corporation
PDP	Parker-Davis Project
Reclamation	Bureau of Reclamation
ROD	Record of Decision
SLCA/IP	Salt Lake City Area Integrated Projects
Upper Basin	Upper Colorado River Basin
U.S.	United States
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

TA 15. Dams and Electrical Power Resources

TA 15.1 Affected Environment

This section provides an overview of the four primary dams and reservoirs in the analysis area of the Colorado River corridor from the full pool elevation of Lake Powell to the Southerly International Boundary: Glen Canyon Dam/Lake Powell, Hoover Dam/Lake Mead, Davis Dam/Lake Mohave, and Parker Dam/Lake Havasu. This section provides the context for analyzing the effects of the alternatives on the electrical power capacity and spillway use of Glen Canyon Dam and Hoover Dam, and the power generation at all four dams. This section also provides the context for analyzing the effects of the alternatives on electricity rates.

Other, smaller dams and hydroelectric facilities in the analysis area include Headgate Rock, Senator Wash, Siphon Drop, and Pilot Knob. Changes to these smaller dams and their associated reservoirs are not being proposed in any of the alternatives, and due to the nature of their operations, there are no anticipated substantial effects on the electrical power capacity, generation, spillway, or safety of these dams nor are there any anticipated substantial effects relative to their electricity rates nor the economic value of the power they produce from the alternatives.

The Bureau of Reclamation (Reclamation) operates and maintains the Glen Canyon, Hoover, Davis, and Parker Dams. The Western Area Power Administration (WAPA) is responsible for marketing and transmitting the power generated at these facilities across the Colorado River Basin (Basin; Reclamation 2007a). As established in the 1922 Colorado River Compact, the Upper Colorado River Basin (Upper Basin) consists of the states of Colorado, New Mexico, Utah, and Wyoming; the Lower Colorado River Basin (Lower Basin) consists of the states of Arizona, California, and Nevada; and Lee Ferry is considered the dividing point between the two basins. Lee Ferry is located 1 mile below the mouth of the Paria River in Arizona. The Colorado River Compact established that each basin would receive 7.5 million acre-feet (maf) of water annually. In 1956, the Colorado River Storage Project Act of 1956 (CRSPA) outlined Upper Basin water storage and management processes to facilitate the apportionment of water in the Upper Basin and the delivery of water to the Lower Basin. This water storage system called for the building of four dams, with Glen Canyon Dam and Lake Powell reservoir serving as the primary water storage infrastructure for the Upper Basin.

TA 15.1.1 Hydropower Generation and Capacity Overview

Hydropower generation occurs when water stored in a reservoir passes through a turbine, which converts the energy of the falling water to mechanical energy, which is then converted to electricity as the turbine turns the rotors in the generating units. The amount of electrical power generated is directly related to the amount of water passing through the turbines and the force, or "head," of the water as it moves through the turbines. The higher the reservoir elevation, the more head the water

can exert when passing through the turbines. Capacity is mainly affected by the depth of the reservoir and the number of generators.

Power generation has two main measurable components: power and energy. Power is the rate at which energy is transferred or consumed, or the amount of electricity produced at a specific time and is measured in megawatts (MW). Energy is the amount of power generated over time and is measured in megawatt hours (MWh). Capacity is the maximum power that can be produced at a specific moment. The physical capacity of a powerplant is the maximum power that results from generator and turbine capacity and reservoir levels. Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates[1]. Physical and firm capacity are measured in MW. This affected environment portion of this technical appendix describes the physical capacity of the Glen Canyon and Hoover Powerplants, and the environmental consequences portion analyzes the effects of the alternatives on the firm capacity of these powerplants as firm capacity takes into account all of the conditions that WAPA and Reclamation use for operational decisions.

Additional information on power generation, control, regulation, reserves, and ramping can be found in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (2007 Final EIS) Section 3.11.1.1 (Reclamation 2007a); and that information is incorporated here by reference.

TA 15.1.2 Hydropower Marketing and Administration Overview

WAPA markets power and administers power contracts for electricity generated from the dams that are specific to each of the hydropower projects. WAPA sets power rates every few years for each hydropower project. The rates cover the operating costs of WAPA and those of the hydropower project (WAPA 2025a). WAPA power sales and transmission operations are organized by region with Glen Canyon Powerplant operating within the Colorado River Storage Project (CRSP) region and Hoover, Parker, and Davis Powerplants operating within the Desert Southwest Region. WAPA bundles and markets power to a variety of entities including: small and medium-sized municipalities that operate publicly owned utilities; irrigation cooperatives and water conservation districts; rural electrical associations; generation and transmission co-operatives; federal facilities; universities; state agencies; and tribes (Reclamation 2016a) across the following states: Nebraska, Wyoming, Utah, Nevada, Colorado, California, Arizona, and New Mexico.

WAPA distributes the power through four types of contracts that are classified as: long-term firm power and other long-term sales; non-firm energy and short-term sales and purchases; seasonal power sales; and purchase power (WAPA 2025a). Firm power contracts guarantee the capacity and energy that will be available 24 hours a day and non-firm contracts come without a guarantee of continuous availability (WAPA 2025a). Firm and non-firm contracts can be short- or long-term.

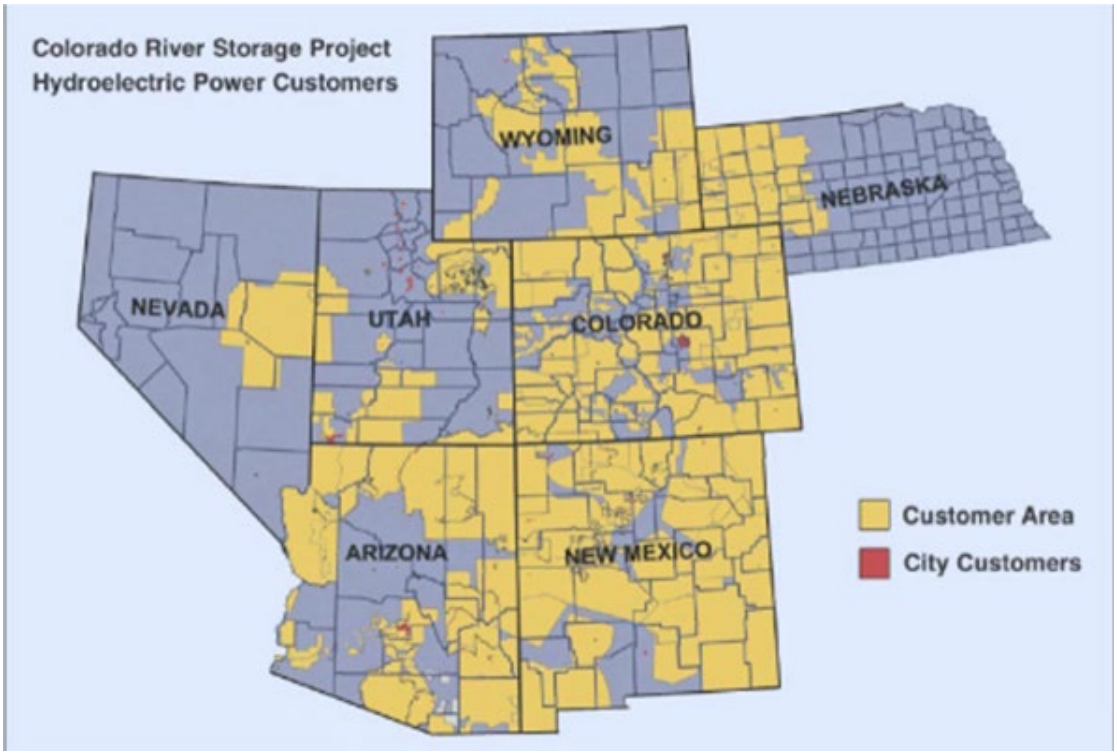
The contracts for Glen Canyon Dam power are effective 2024 through 2057 (WAPA 2023). There are more than 100 customers for Glen Canyon Dam power, and they provide electricity within the states of Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, and Nebraska. WAPA markets

[1] The ramp rate is the rate of change in instantaneous output from a powerplant. The ramp rate is established to prevent undesirable effects due to rapid changes in loading or discharge.

Hoover Dam generated power to 46 customers and Parker Dam and Davis Dam generated power to 36 customers within southern Nevada, Arizona, and southern California. Hoover Dam power is marketed as a long-term contingent capacity contract with associated energy. This means that WAPA is obligated to deliver the energy that can be generated from the available capacity. The new contracts for Hoover Dam took effect on October 1, 2017, and expire on September 30, 2067. The Parker Dam and Davis Dam power is marketed as long-term, firm contracts. Contracts for the Parker Dam and Davis Dam were signed prior to 2007 and terminate in 2028. WAPA anticipates signing new contracts that will replace the expiring contracts.

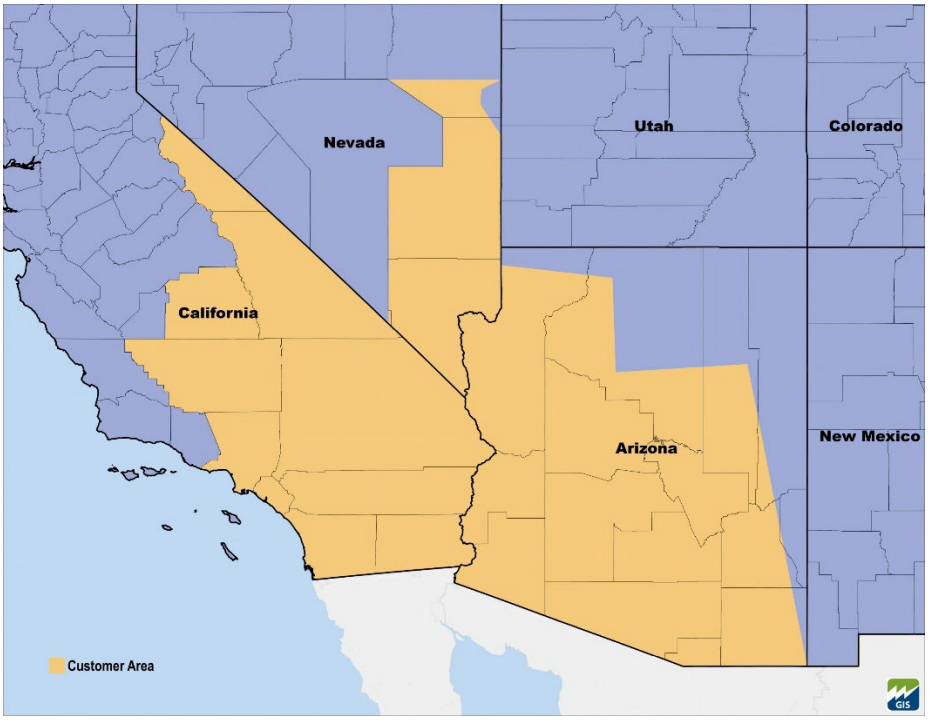
The Basin is within what is referred to as the Western Interconnection region of the Western Electricity Coordinating Council (WECC). The WECC is a regional, non-profit corporation that oversees bulk electrical system reliability planning and assessment. The Western Interconnection area includes two Canadian provinces, 14 western states, and the northern United Mexican States (WECC 2025). The Glen Canyon, Hoover, Parker, and Davis Powerplants account for approximately 2.2 percent of the total electrical capacity within the Western Interconnection region. **Figure TA 15-1** identifies the CRSP hydroelectric power customers located within the Western Interconnection, illustrating the geographic distribution of entities that receive power generated from Basin facilities. Similarly, **Figure TA 15-2** shows WAPA's Desert Southwest Region's service area map which provides electric service to customers in Arizona, southern California, and southern Nevada.

Figure TA 15-1
CRSP Hydroelectric Power Customers



Note: Glen Canyon Dam is a feature of CRSP.

Figure TA 15-2
Desert Southwest Region Hydroelectric Power Customers



Note: Hoover, Parker, and Davis Dams are features of the Desert Southwest Region.

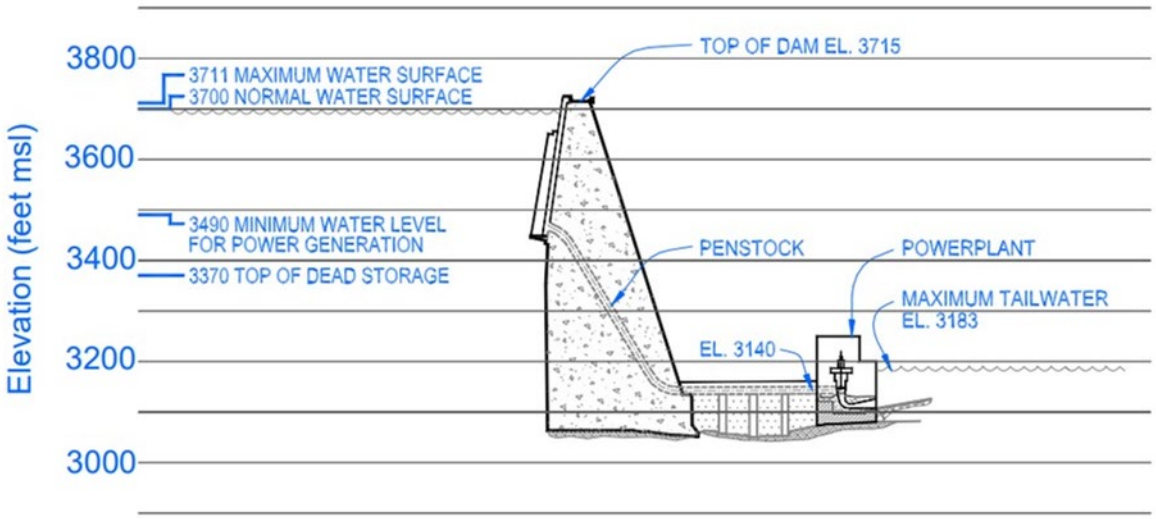
TA 15.1.3 Infrastructure Conditions and Hydroelectric Power Generation and Capacity

This section provides an overview of the infrastructure conditions of the Glen Canyon Dam/Lake Powell reservoir, the Hoover Dam/Lake Mead reservoir, Davis Dam/Lake Mohave reservoir, Parker Dam/Lake Havasu reservoir, and their hydropower capacity and generation.

Glen Canyon Dam/Lake Powell

Glen Canyon Dam is located in Page, Arizona and is a concrete arch dam rising 710 feet with a 35-foot-wide roadway connecting the dam's spillways, see **Figure TA 15-3**. The dam's reservoir, Lake Powell, has a water storage capacity of 25.16 maf and a maximum reservoir elevation of 3,711 feet. The dam and reservoir are operated and maintained by Reclamation's Glen Canyon Field Division in Page, Arizona.

Figure TA 15-3
Lake Powell and Glen Canyon Dam Important Operating Elevations



Water Releases and Operational Considerations

During normal operating conditions, water is released from Glen Canyon Dam through the Glen Canyon Powerplant through intakes on the upstream face of the dam. Eight, 15-foot steel penstocks convey water to the powerplant turbines through an elevation drop of 330 feet to a centerline elevation of 3,140 feet. Water cannot be released from the penstocks below a Lake Powell elevation of 3,490 feet (which is known as the minimum power pool and is 20 feet above the penstock intake centerline). At an elevation of 3,490 feet, it is estimated that vortex formation would begin to occur at the powerplant. As described in **Section 1.8.4.1**, there are also infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs. Releases in excess of powerplant capacity are made when flood conditions are caused by high runoff in the Upper Basin or when high-flow experiments (HFEs) are triggered downstream. Historically, these releases are well above 3,490 feet. However, HFEs can be conducted down to an elevation of 3,500 feet.

Four, 96-inch steel pipes comprise the river outlet works at a centerline elevation of 3,374 feet. The outlets have a maximum combined capacity of 15,000 cubic feet per second (cfs) at elevation 3,500 feet. Below 3,500 feet the capacity decreases. Below minimum power pool, the outlet works are the sole means of releasing water. An annual release of 8.23 maf equates to a continuous flow of up to 11,368 cfs. With all four outlets operational, this release can be maintained down to approximately elevation 3,440 feet, however, operations and maintenance constraints may limit these releases or the elevation. Since the construction of Glen Canyon Dam, the river outlet works are typically reserved for flood control, HFEs, augmenting powerplant and spillway discharges, or for periods when the powerplant is not operating.

Dam operations are managed to maintain the water surface elevation near or below 3,700 feet, which is the normal operating level. Operational preference is to maintain a water surface elevation below the top of active conservation, 3,700 feet, to minimize the occurrence of flood operations and the need for additional monitoring. Glen Canyon Dam is designed to safely accommodate the probable maximum flood including operating up to the maximum water surface elevation of 3,711 feet.

Another important operational consideration is maintaining adequate vacant storage around elevation 3,684 feet on January 1, which provides necessary capacity for managing inflows from spring runoff.

In 1983, heavy late-winter mountain snow accumulation within the Basin created 150 percent of normal runoff, causing the first real use of the Glen Canyon spillway. High, extended releases through the spillways (up to 27,000 cfs from the right spillway and 32,000 cfs from the left) caused serious cavitation damage within the tunnel, particularly in the vertical bends. Cavitation is the formation of vapor cavities in a liquid. As the vapor cavities move into a zone of higher pressure, they collapse, sending out destructive high pressure shock waves (Reclamation 2019). The 1983 damage led to the installation of 4-by-4-foot air slots in the spillways to prevent future cavitation damage by introducing air into the water flow.

Current Condition

Reclamation, utilizing the Dam Safety Priority Rating (DSPR) system, evaluated Glen Canyon Dam and gave it a DSPR 5 category rating. This is Reclamation's lowest-priority rating from a dam-safety risk standpoint, indicating the facility poses the lowest risk to the public. The total mean annualized failure probability of static, hydrologic, and seismic risks to the dam is 3 orders of magnitude below Reclamation's Public Protection Guideline.

Maintenance tasks for the river outlet works include lining repairs and hollow-jet valve maintenance. The interior of the river outlet works was originally lined with coal tar enamel. Relining of the river outlet works with solvent borne epoxy began in the fall of 2024. The fabrication of the river outlet works hollow-jet valves dates back to the original construction of the dam, with no rehabilitation since that time. In 2023, an inspection of the outlet works found that to continue long-term operation of the outlet works, major repairs or replacement of the hollow-jet valves should be considered, as well as increasing the frequency of regular operation and maintenance tasks. River outlet works conduits were relined between 2024 and 2025. Refurbishment or replacement of the hollow jet valves is in the planning stages.

Operations

The operating criteria for Glen Canyon Dam were published in 1997. The Glen Canyon Powerplant operating regime was modified with the 2016 Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Record of Decision (ROD), which establishes guidelines for allocating annual release volumes and defines a minimum water release rate of 8,000 cfs or more between 7:00 a.m. and 7:00 p.m., and at least 5,000 cfs between 7:00 p.m. and 7:00 a.m.; the maximum hourly increase (that is, the up-ramp rate) of 4,000 cfs per hour; a daily fluctuation limit of 8,000 cfs per 24-hour period; and a water maximum release rate of 25,000 cfs (Reclamation 2016b). The 2016

LTEMP ROD modified the daily fluctuation limit, so it is calculated as a function of the monthly volume, and it increased the down-ramp rate to no greater than 2,500 cfs per hour (Reclamation 2016b).

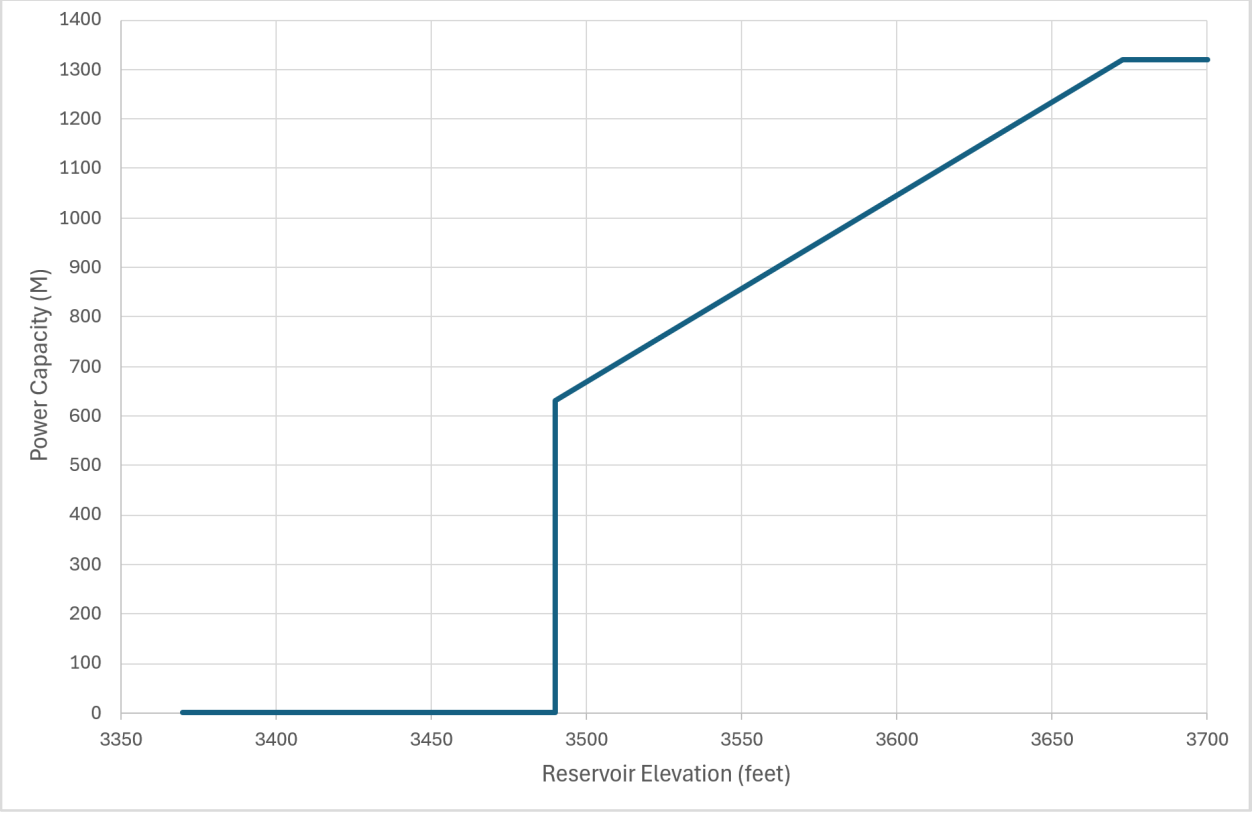
Hydropower Generation and Physical Capacity

Glen Canyon Powerplant has eight generators with a maximum combined physical capacity of 1,320 MW at a reservoir elevation of 3,700 feet (Reclamation 2016a). At minimum power pool, the powerplant has an estimated physical capacity of 630 MW.

Since 2007, the powerplant has undergone updates to improve efficiency, including: replacement of all eight turbines, four generator rewinds, replacement of all step-up transformers, optimization of software within the facility; and continued operations and maintenance (Reclamation 2024).

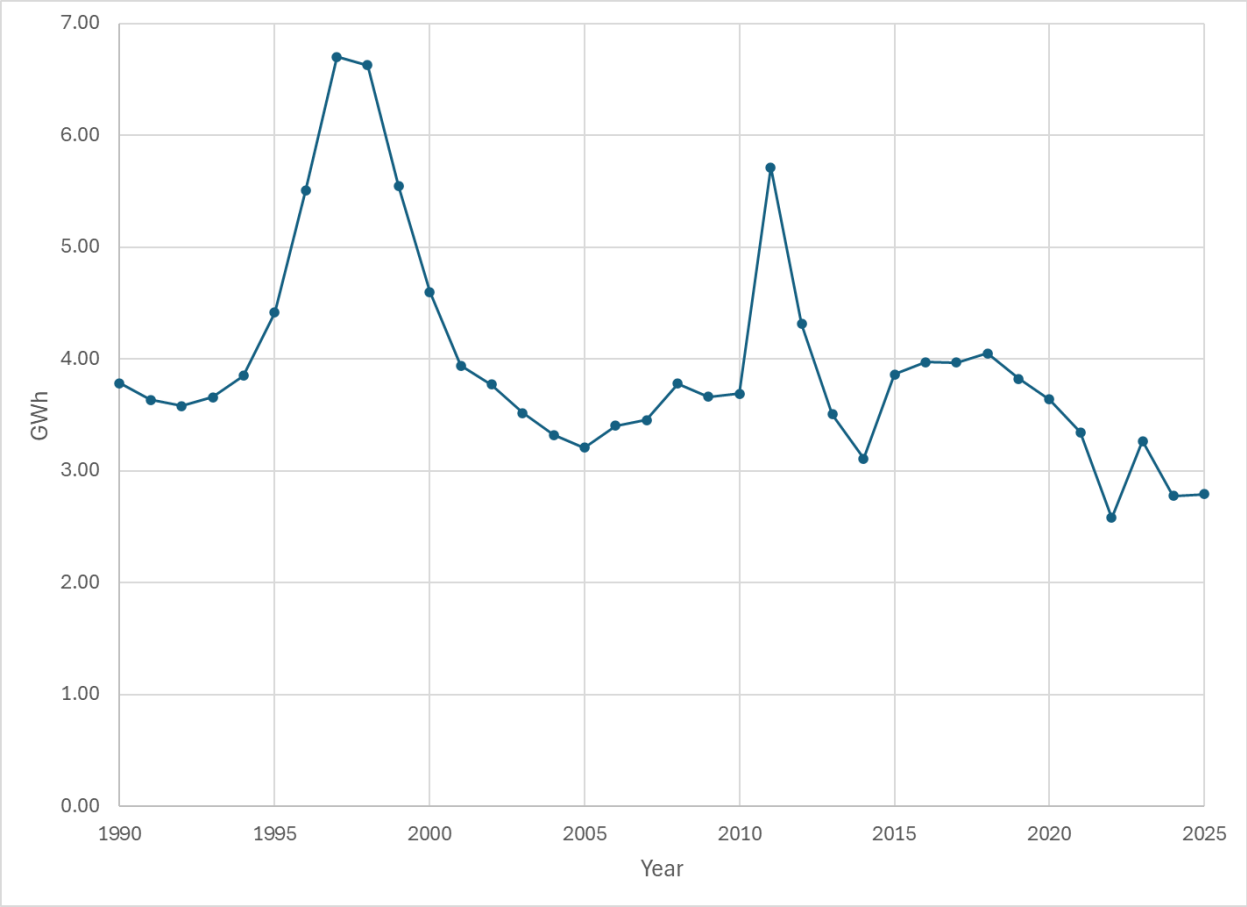
Despite the improved efficiencies, the powerplant's physical capacity to generate power has been affected by drought conditions and the resulting decreases in Lake Powell reservoir elevations. The decreases in elevation and, therefore, head, combined with reduced annual releases, have reduced power generation since 1997. **Figure TA 15-4** below shows the estimated physical capacity at a range of lake elevations. **Figure TA 15-5** displays the historical annual power generation from 1990 to present.

Figure TA 15-4
Power Capacity Estimates for Glen Canyon Powerplant at Varying Lake Powell Elevations



Source: Reclamation 2025a

Figure TA 15-5
Annual Glen Canyon Powerplant Generation from 1990 to Present

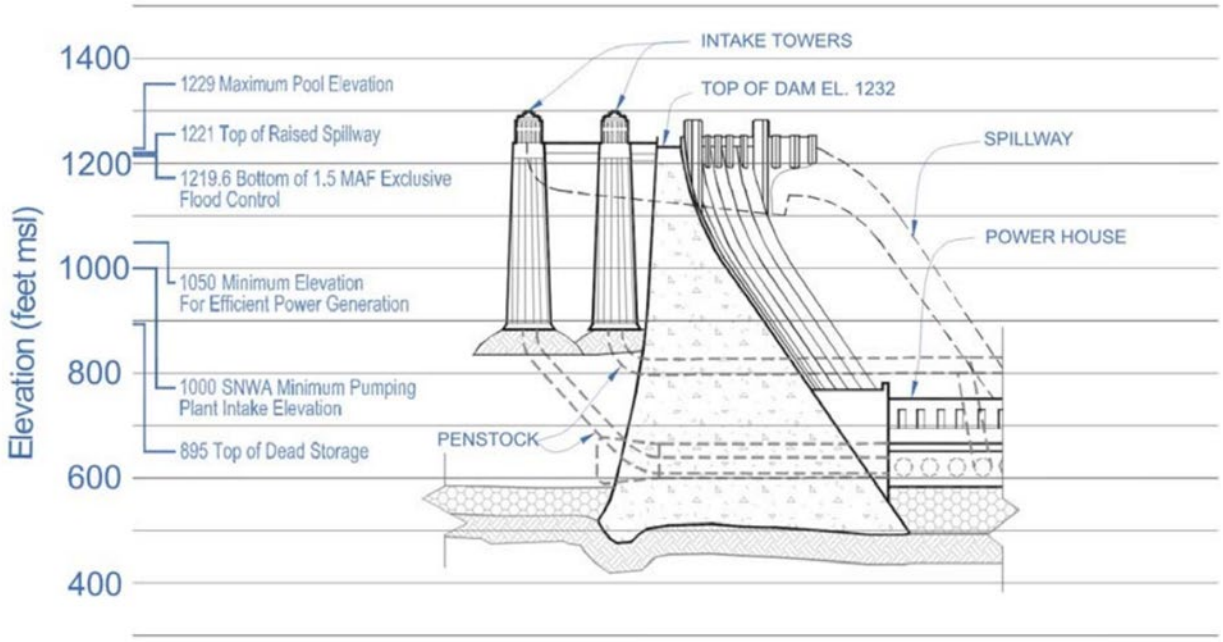


Source: Reclamation 2025a

Hoover Dam/Lake Mead

Hoover Dam is located in Black Canyon on the Arizona-Nevada state line, approximately 35 miles southeast of Las Vegas, Nevada. The dam and its reservoir, Lake Mead, are operated and maintained by Reclamation's Lower Colorado Basin Dams Office. Hoover Dam is a concrete gravity-arch structure standing 726 feet high with a crest length of 1,244 feet, see **Figure TA 15-6**. Lake Mead has a water storage capacity of 30.2 maf and a maximum reservoir elevation of 1,232 feet.

Figure TA 15-6
Lake Mead and Hoover Dam Important Operating Elevations



Water Releases and Operational Considerations

Effective power generation currently requires a minimum water elevation of 950 feet in Lake Mead (Reclamation 2024). Water levels between 895 and 950 feet constitute the inactive pool, where releases can occur but do not generate hydropower. Below 895 feet, water reaches dead pool elevation, at which point releases are no longer possible.

Water is released from Lake Mead to the river through four intake towers. These 395-foot-high towers are positioned two on each side of the canyon and each tower has two openings for water to enter the penstocks, one near mid-height at elevation 1,045 feet and one at the bottom at elevation 895 feet. These openings can be closed by two 32-foot diameter, 11-foot-tall cylindrical gates. The two upstream intake towers release water to the lower main penstocks. The two downstream intake towers release water to the upper main penstocks. Each main penstock has four 13-foot-diameter steel penstocks that connect to the main penstock and supply water to individual generator turbines. The combined discharge capacity of all generator turbines is estimated at 49,000 cfs.

In addition, to passing water through the turbines, at the end of each main penstock are outlet works. At the end of each of the main penstock the penstock pipe branches into smaller diameter penstocks controlled by outlet work valves. Each of the lower penstocks have 4 valves available to discharge water. The discharge capacities for the lower outlet works are 15,300 cfs (Nevada penstock) and 15,400 cfs (Arizona penstock) at a reservoir water surface elevation of 1,219.6 feet, which is the bottom of the exclusive flood control space. Each of the upper main penstocks have 2 valves available to discharge water, the discharge capacities for the upper outlet works are 10,800 cfs (Nevada) and 10,700 cfs (Arizona) at elevation 1,219.6 feet.

There are two spillways at Hoover Dam, each consisting of a concrete overflow crest structure and basin with four spillway drum gates each, and a concrete-lined tunnel that discharges directly into the Colorado River. The original discharge capacity of both spillways was 400,000 cfs, but the maximum safe discharge capacity for each spillway was reduced to approximately 135,000 cfs due to the formation of a hydraulic jump inside the tunnels at those flows or greater.

Under normal conditions, nearly all Colorado River flow passes through the turbines, with the spillways and outlet works used only in exceptional circumstances. The maximum safe channel capacity is estimated to be 40,000 cfs. Current operations aim to keep Lake Mead below 1,219.6 feet as much as possible. While limited operation above this level has occurred historically, it is preferred to minimize time spent in the flood control space. The bottom of the spillway drum gate is 1,205.4 feet. Operating below this elevation is desired as elevations above this point rely on mechanical gate function, where risk of failure increases. The most critical elevation threshold is 1,226.9 feet. This elevation corresponds to a spillway discharge exceeding 40,000 cfs and represents an imminent emergency.

Current Condition

The DSPR system evaluated Hoover Dam to be in the DSPR 5 (low priority, normal urgency of action) category. The total mean annualized failure probability for static, hydrologic, and seismic risks remains three orders of magnitude below Reclamation's Public Protection Guideline threshold.

Water conveyance systems at Hoover Dam are generally in good condition. The intake towers and penstocks are more than 85 years old and part of the original construction of Hoover Dam. The intake towers and penstocks cannot be replaced, and routine maintenance is required to maintain structural integrity. As part of the routine maintenance program, the penstocks are drained, inspected, and the coating is repaired as needed.

In August 1941, Lake Mead's water level was within 1 foot of the spillway crest when the spillway gates were lowered, allowing flows for the first time. Relatively modest flows, never exceeding 13,000 cfs, were passed through both spillways for 4 months. Velocities reached up to 175 feet-per-second in the Hoover Dam spillway elbow. When halted in early December 1941, an inspection of the Arizona spillway tunnel revealed a 38- by 112-foot eroded section of tunnel lining due to flow cavitation that required repairs. The 1941 damage was attributed to a slight misalignment of the tunnel invert. In response to this finding, the tunnels were patched with special heavy-duty concrete and the surface of the concrete was polished smooth. The spillways were subsequently modified in 1947 by adding flip buckets to eliminate conditions thought to have contributed to the 1941 damage.

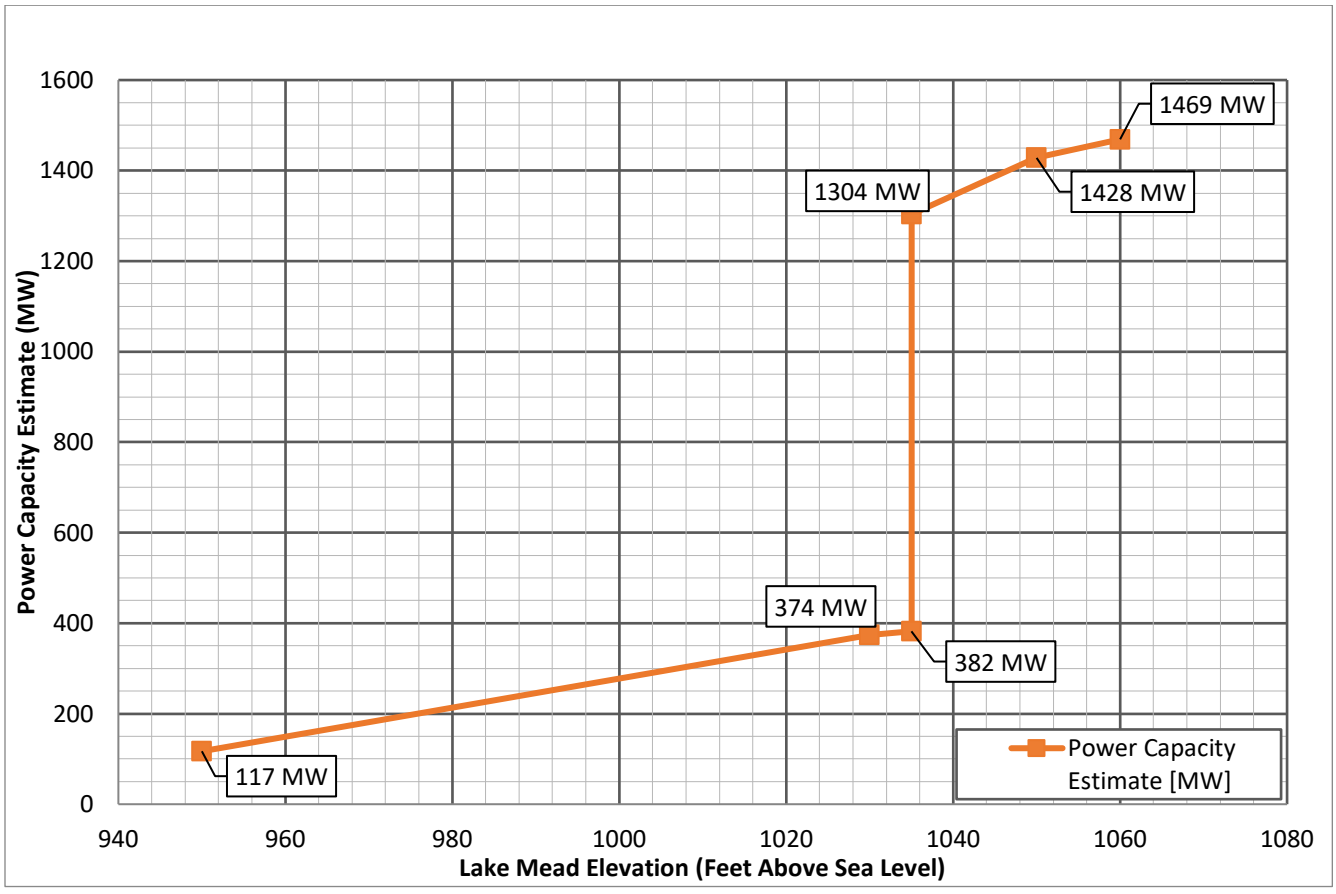
Operations

The Hoover Dam water releases are highest in the spring and summer with daily fluctuations made to meet water demands downstream as well as meet hydropower demand. The total range of flood control releases from Hoover Dam are from Step 1 - 0 cfs to Step 6 - 73,000 cfs (Reclamation 2007b). Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaks during high-demand periods. Releases from Hoover Dam are also based on flood control regulations that are operated by the United States (U.S.) Army Corps of Engineers. Approximately 1.5 maf of space must be reserved at all times exclusively for flood control purposes.

Hydropower Generation and Physical Capacity

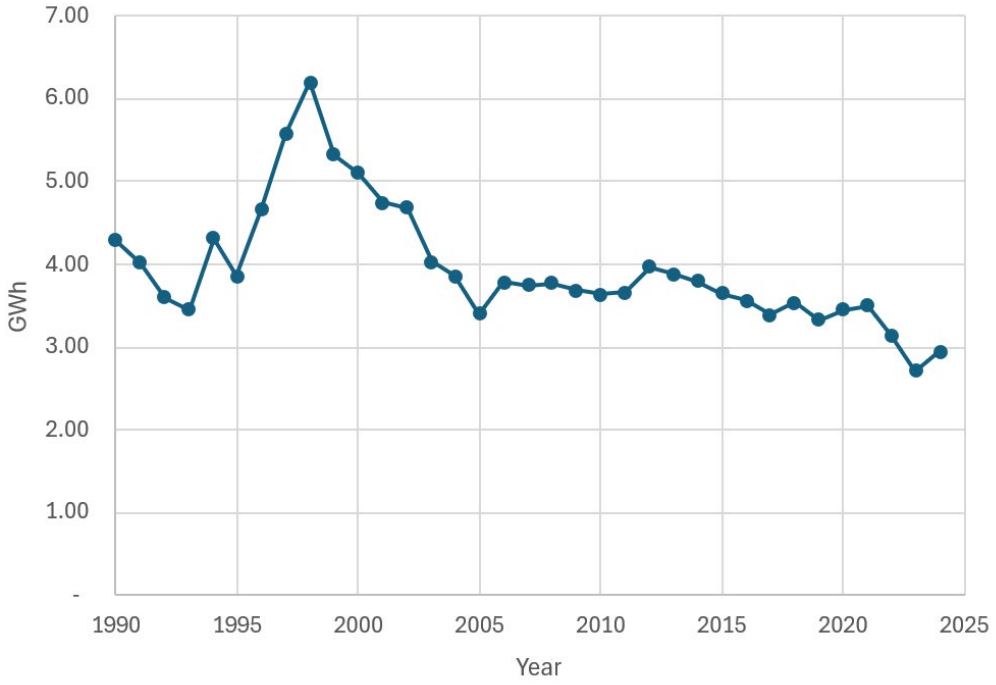
The Hoover Powerplant is the largest hydropower-generation facility in the Basin. The Hoover Powerplant has seventeen commercial generators with a maximum combined capacity of 2,074 MW. The powerplant requires a minimum Lake Mead elevation of 950 feet to produce power. At minimum power pool, the powerplant has an estimated physical capacity of 117 MW. The power-generating capacity of Hoover Dam has been affected by drought conditions. The drop in Lake Mead's elevation has reduced head, lowering electric power output. At Lake Mead elevation 1,035 feet, Hoover Dam's generating capacity is drastically reduced from 1,274 MW to 382 MW. At elevations above 1,035 feet or greater in current market conditions, hydropower can be produced at or above market value. With current turbines, if the elevation drops below 1,035 feet, it is estimated that operating costs will exceed the value of the hydropower produced. Please reference **Figure TA 15-7** and **Figure TA 15-8** below.

Figure TA 15-7
Power Capacity Estimates for Hoover Powerplant at Varying Lake Mead Elevations



Source: Reclamation 2025b

Figure TA 15-8
Annual Hoover Powerplant Net Generation from 1990 to 2024



Source: Reclamation 2025c

Since the 2007, Reclamation has replaced five existing turbines at the powerplant with "wide-head" turbines, upgraded wicket gates, modernized unit controls, and conducted typical operations and maintenance of the facility. The upgraded turbines, wicket gates and modernized unit controls have increased efficiency. However, at elevation 1,035 feet Hoover Dam would only be able to use its five wide head turbines. The 12 older turbines are expected to get excessive cavitation damage and would not be used. In May 2026, Reclamation announced $52 million from the Hoover Dam Post Retirement Benefit fund will be used for replacement of up to three older turbines with wide-head turbines designed to operate at lower lake elevations.

Despite the increased efficiencies, the power generating capacity of Hoover Dam has been affected by drought conditions. **Figure TA 15-7** shows the estimated electric power capacity at a range of Lake Mead elevations. **Figure TA 15-8** displays the historical annual power generation from 1990 to present. The decrease in the elevation of the Lake Mead reservoir has led to a decrease in head, which has resulted in a decrease in electric power output.

Davis Dam/Lake Mohave and Parker Dam/Lake Havasu

Davis Dam is a 320-foot-tall rock and earth-fill gravity dam, rising 140 feet above the Colorado River. The dam spans the border of Arizona and Nevada in Pyramid Canyon and is 67 miles downstream from Hoover Dam. Its dam crest is 1,600-feet long and 50-feet wide. Its reservoir, Lake Mohave has a water storage capacity of 1.8 maf and a maximum reservoir elevation of 647 feet. Davis Dam is operated and maintained by Reclamation's Davis Dam Field Division which is part of the Lower Colorado Basin Dams Office.

Parker Dam, commonly known as the "deepest dam in the world," is a concrete arch structure, 320 feet tall, with 73 percent of its height below the original stream bed elevation of the Colorado River. The dam is on the Arizona and California border and 88 miles downstream from Davis Dam. The dam has a crest length of 856 feet and a width of 39 feet. The dam's reservoir, Lake Havasu, has a storage capacity of 646,200 acre-feet and a maximum reservoir elevation of 450 feet. Parker Dam is operated and maintained by Reclamation's Parker Dam Field Division of the Lower Colorado Basin Dams Office.

Water Releases and Operational Considerations

Davis Dam has a rectangular concrete forebay at its eastern end. At the end of the forebay is a spillway that consists of three 50-foot x 50-foot fixed wheel gates and a spillway crest elevation of 597 feet. The river outlet works consist of 22-foot x 19-foot radial gates with a crest elevation of 542 feet. From the forebay, water enters the powerplant through five 22-foot diameter steel lined penstocks to five hydroelectric generators. The powerplant can release up to 26,000 cfs at 120 feet of head and 31,000 at 136 feet of head. Normal releases from Davis Dam are made through the powerplant turbines with the spillway and outlet works in the closed position. The safe downstream channel capacity on the river is 40,000 cfs. Normal operating elevations for the Lake Mohave reservoir are between 630 and 646 feet.

Parker Dam has a forebay on the right downstream abutment. In the center of the dam is a spillway that consists of five 50-foot-wide overflow gate bays at the dam center with a crest elevation of 400 feet. From the forebay water enters the powerplant through four 22-foot diameter steel lined penstocks that convey water to four hydroelectric generators. Their combined discharge capacity is 22,000 cfs. The safe downstream channel capacity on the river is 40,000 cfs. The normal operating elevations for the Lake Havasu reservoir are between 445 and 450 feet.

Current Condition

The DSPR system evaluated Davis and Parker Dams to be in the DSPR 4 (low urgency of action) category, as the total mean annualized failure probability of static and seismic risks to the dams is one-half order of magnitude below Reclamation's Public Protection Guideline threshold value. The dams were determined to be in good condition and performed adequately, and responses of the dams to reservoir loading are predictable, with conditions not appearing to change.

Operations

The Davis Dam fluctuates releases between 4,200 cfs and 23,000 cfs, while Parker Dam fluctuates between 1,800 cfs and 19,000 cfs. The maximum releases for the Parker and Davis Powerplants are 19,000 cfs and 23,000 cfs, respectively. The exact release depends on downstream water demands and tends to be lowest during the winter and highest in spring and summer. Parker Dam is operated under the same rule curve that determines end-of-month target elevations as prior to the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead, maintaining Lake Havasu's water surface elevation between 445 and 450 feet. Seasonal adjustments to the reservoir's water surface elevation allow for flood control in the fall and higher water levels in the spring. The average annual elevation was 447.5 feet from 1996 to 2007, and approximately 447.7 feet from 2008 to 2022, remaining consistent for the last several decades. Current minimum releases of the Parker Dam are 1,600 cfs daily, 1,400 cfs hourly, and

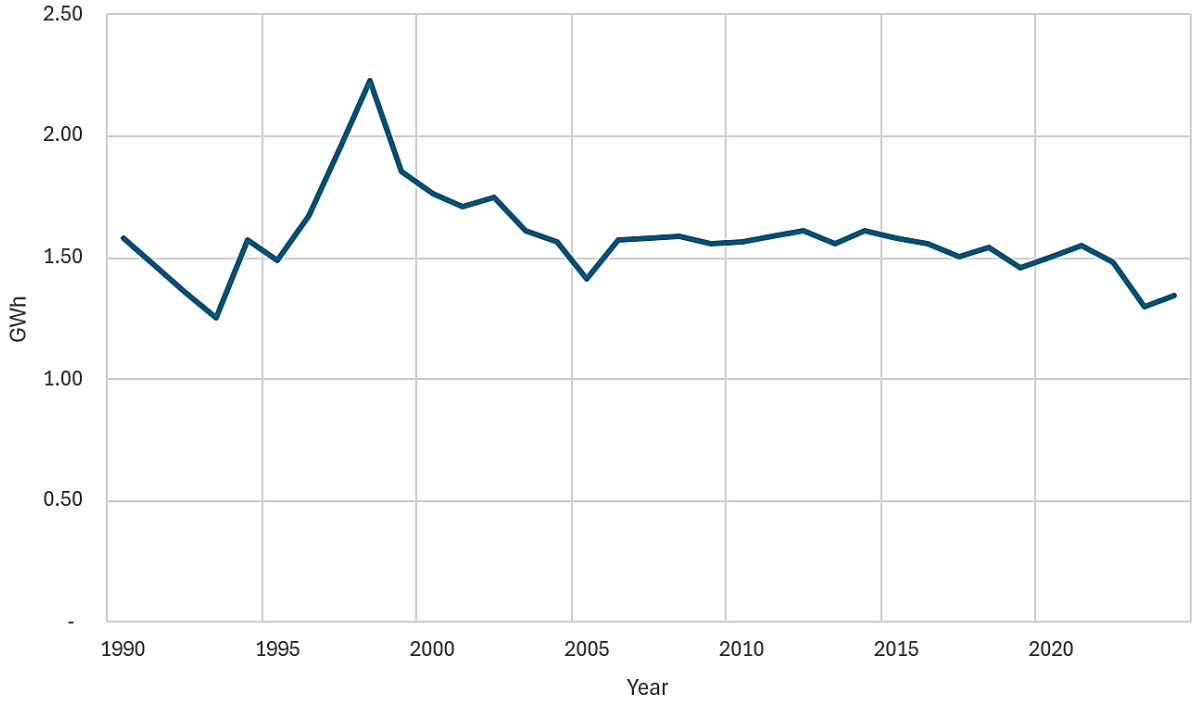
95,000 acre-feet during a 30-day month. The 2007 Final EIS stated Parker Dam releases from Lake Havasu ranged from 6.19 maf to 10.3 maf (averaged 7.4 maf) from 1996 to 2007 (Reclamation 2007a). Since 2008, annual dam releases ranged from 6.2 maf to 6.7 maf (averaged 6.4 maf) through 2022. The average annual Parker Dam releases have decreased by 1.0 maf since the issuance of the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead.

Hydropower Generation and Physical Capacity

The Davis Powerplant has four 51.75 MW generators and one 48 MW generator for a total of 255 MW of capacity. The Parker Powerplant has four 30 MW generators, totaling 120 MW, with a discharge capacity of 22,000 cfs (Reclamation 2023).

Since 2007, both the Davis and Parker Dam facilities have undergone typical operations and maintenance. All four turbines at the Parker Powerplant were replaced between 2004 and 2010. Drought conditions have had less impact on the capacity at Davis and Parker Powerplants than the Hoover and Glen Canyon Powerplants because the elevations of Lake Mohave and Lake Havasu reservoirs have remained relatively constant. **Figure TA 15-9** shows the historical combined annual power generation at the Parker and Davis Powerplants. The slight drought induced reduction in river flow has led to a decline in electric power generation.

Figure TA 15-9
Annual Parker and Davis Powerplants Generation from 1990 to Present



Source: Reclamation 2025a

TA 15.1.4 Hydroelectrical Power Distribution

Hydroelectric power generation can be adjusted operationally through a coordinated effort between WAPA and Reclamation. This operational flexibility allows WAPA to quickly and efficiently increase or decrease generation in response to customer demand, generating unit or transmission line outages (contingency reserves), unscheduled customer deviations from internally scheduled contracted power usage (regulation and load/generation following) within a specific metered load area known as a balancing authority, integrated power system requirements, and requests for emergency assistance from interconnected utilities. Power operations are the physical operations of an electric power system, including hydropower generation and control, operational flexibility, scheduling, power generation load following, regulation, transmission, and emergency operations. These are discussed in the sections below. Additional information on power generation, control, regulation, reserves, and ramping can be found in the 2007 Final EIS Section 3.11.1.1 (Reclamation 2007a); and that information is incorporated here by reference.

Scheduling[2]

Power scheduling occurs by matching available power generation to seasonal, daily, and hourly system energy and capacity needs. Power scheduling is affected by the temporal distribution of monthly water release volumes, restrictions in water release patterns, availability of generator units (due to maintenance), availability of other regional hydropower units, power allocations, and peak and off-peak power demand period. Glen Canyon Dam scheduling by WAPA to meet power requirements typically results in higher water releases via the powerplants in the peak power demand months of December, January, July, and August. In the Lower Colorado River dams, scheduling is driven by water orders. There is high degree of flexibility in the releases within a month for Hoover Dam, but the amount of power delivered is constrained by monthly water orders. For Parker Dam and Davis Dam the scheduling occurs daily for power based on water orders.

Load Following,[3] *Ancillary Services, Generation, and Regulation*[4]

Hoover Dam and Glen Canyon Dam can change in response to changes in the load (demand) or unanticipated changes in the power generation resources within the operating region. This ability to respond to rapidly changing load conditions is called load or generation following (Reclamation 2016a). Load following creates large fluctuations in water releases, which can have impacts on some downstream environmental resources (Reclamation 2016a). The 1996 Operation of Glen Canyon Dam: CRSP ROD (Reclamation 1996) narrowed the range of operation for CRSPA purposes, thereby reducing the ability of power generation at Glen Canyon Dam to respond to customer load.

Changes in WAPA's scheduling guidelines for Glen Canyon Dam typically occur over a period of months, not only because of the operational constraints originally imposed by the 1996 Glen Canyon Dam ROD (Reclamation 1996) but also due to changing market conditions. Operational conditions for Glen Canyon Dam are further affected by the frequency, season, and time-of-day

[2] Scheduling information is provided for context. The alternatives do not address scheduling and there are no anticipated impacts on scheduling from the alternatives.
[3] Load following are adjustments to power output as demand for electricity fluctuates throughout the day.
[4] Load following, ancillary services, generation, and regulation information is provided for context. The alternatives do not address load following, generation, or regulations and there are no anticipated impacts on them from the alternatives.

limitations that may be in effect; physical and environmental operating restrictions at other CRSP generating facilities and within the interconnected electric system; and the availability and price of replacement power (Reclamation 2016a).

National Regional Reliability Standards[5]

To ensure interconnected system reliability, WAPA follows mandatory reliability standards enforced by the North American Electric Reliability Corporation (NERC) and the WECC. In addition, WAPA follows operational criteria, guidelines, and procedures set in place by the WECC and the contingency reserve sharing group applicable to each balancing authority area. Each WECC utility is located within such a load balancing area, and one utility within the balancing authority area serves as the balancing authority operator. WAPA is the balancing authority operator for the Southwest Power Pool Regional Transmission Organization Balancing Authority Areas and is responsible for ensuring that each load-serving utility within each balancing authority serves its own internal load while meeting its power and reserve obligations. Operating as a balancing authority, WAPA is the provider of last resort should a load-serving entity not be able to fulfill its obligation to the balancing authority area, and it carries all compliance responsibility for the balancing authority function. All CRSP powerplants are within the Western Area Colorado-Missouri Region balancing authority, and the flexibility and load/generation following capability of CRSP hydroelectric powerplants, particularly Glen Canyon Powerplant, are important in meeting NERC/WECC reliability standards and criteria. Hoover, Parker and Davis Powerplants are all within the Western Area Lower Colorado balancing authority area. Hoover provides ancillary services including regulation capability through a dynamic or pseudo tie generation arrangement with four other balancing authority areas including significant capacity allocations that can provide regulation services within the California Independent System Operator.

Colorado River Storage Project Basin Fund[6]

The CRSPA; 43 U.S. Code 620d) established the Basin Fund for the collection of revenues from the operation of the CRSP and participating projects. These funds are available until expended to defray the costs of operation, maintenance and replacements for all facilities of the CRSP and participating projects. Maintaining a sufficient Basin Fund balance is critical to operating and maintaining the reliability of CRSP facilities. Reclamation and WAPA use this fund to repay the federal investment (with interest), operate and maintain facilities, purchase market power, when necessary, provide funding under a Basin States' memorandum of agreement, support environmental and salinity programs, and provide irrigation assistance. WAPA sells wholesale power to preference customers, including public utilities, municipalities, and tribes, which incorporate this power into the rest of their portfolio to fulfill their load requirements. Under WAPA's current rate structure, WAPA provides its long-term firm power customers with a set amount of power on a quarterly basis. The amount of power is based on the amount of water Reclamation forecasts to release from the CRSP units during that quarter. If the CRSP units do not generate enough power to fulfill these quarterly obligations, WAPA purchases power and necessary transmission to make up the difference. Revenues collected through WAPA's firm power rate from the sale of wholesale power are

[5] National/Regional Reliability Standard information is provided for context. The alternatives do not address these standards and there are no anticipated impacts on them from the alternatives.
[6] Basin Funds are discussed for context. The Basin Fund will not be impacted by the alternatives because it is a reimbursable fund. Any changes in generation would be offset by changes in rates.

deposited into the Basin Fund. Changes in generation identified in the alternatives will not impact the Basin Fund. The Basin Fund has historically funded environmental programs like the Glen Canyon Dam Adaptive Management Program and the San Juan River Basin Endangered Fish Recovery Programs. In recent years, appropriations have funded these base programs, while the Basin Fund continues to fund related experiments. Experimental releases that bypass the electrical generators at Glen Canyon Dam reduce hydropower generation. Accordingly, WAPA purchases replacement power to fulfill contractual delivery obligations. Under the Grand Canyon Protection Act of 1992 (Public Law 102-575), WAPA records the financial cost of environmental experiments at Glen Canyon Dam as a non-reimbursable expense. WAPA accounts for such costs as a constructive return to the U.S. Treasury rather than as an operations and maintenance expense to be recovered through WAPA's cost-based power rates.

Colorado River Dam Fund

The Boulder Canyon Project (BCP) Act of 1928 established the Colorado River Dam Fund to pay for the construction, operation and maintenance of the BCP, including Hoover Dam. All revenues generated by the project, primarily from power sales, are deposited into this fund, which is then used to repay the U.S. Treasury for the construction costs, cover operation and maintenance expenses, and fund other beneficial purposes like flood control, water delivery for Reclamation, and payments to Arizona and Nevada. In addition, surcharges are added to the charges of Nevada and California power contractors to contribute money for the salinity program. Arizona power contractors pay a surcharge for the repayment of the Central Arizona Project. BCP power contractors also contribute to the Lower Basin Multi-Species Conservation Program.

Each year WAPA and Reclamation present the proposed budget for the next ten years with a focus on the next fiscal year to the power contractors. The costs for each fiscal year budget amount is collected from the BCP power contractors and is referred to as the base charge. Each power contractor pays their contractual share of the base charge collected as an energy and capacity component. The base charge value, along with the projected energy generation which is derived from projected water deliveries for the next year creates an implied rate that is used for comparative purposes. The funds collected cover the cost of Reclamation and WAPA for operating and maintaining Hoover Dam and all associated project transmission and facilities.

Parker-Davis Project

The Rivers and Harbor Act of 1935 authorized the construction of Parker Dam. The Davis Dam Project was authorized under provisions of the Reclamation Project Act of 1939. The Consolidate Parker Dam Power Project and Davis Dam Project Act of May 28, 1954, 68 Stat. 143 authorized the Parker Dam Project and the Davis Dam Project to be consolidated into the Parker-Davis Project (PDP). As a result of original project funding, Metropolitan Water District of Southern California holds a perpetual contract for 50 percent of the power generated by the Parker Powerplant.

Reclamation Fund

WAPA has Firm Electric Service Contracts with power contractors. Under the PDP marketing plan, a set amount of monthly power is provided to the power contractors and power revenues are collected into the Reclamation Fund. If power from PDP is not generated to fulfill these contractual power obligations, WAPA purchases power to make up any difference. WAPA uses cash through

their receipt authority from the Reclamation Fund to make those purchases. In 1998, Reclamation entered an Advancement of Funds Contract with the majority of the power contractors to directly fund their costs for Davis Dam and half of Parker Dam. In addition, Reclamation receives monthly transfers from WAPA for the surplus revenues collected under the 4-1/2 mills per kilowatt (kW) hour in the rates charged to power contractors in Arizona for repayment of the Central Arizona Project and 2-1/2 mills per kW hour in the rates charged to power contractors in California and Nevada for the Salinity Program pursuant to the Hoover Power Plant Act of 1984, as amended and supplemented. These funds are recorded as a pass though in PDP and are transferred to the Lower Colorado River Basin Development Fund.

Disturbances and Emergencies and Outage Assistance[7]

In the event of a widespread sudden loss of generation resource power outage, or an imbalance in the transmission system element causing a load/resource imbalance requiring an immediate response (i.e. disturbance), NERC contingency reserve standards require that available generation capacity be utilized to return the electric generation and transmission system to normal operating conditions within load/generation balance within 10 minutes following the disturbance. Generally, emergency operations contingency reserves are needed only for periods of an hour or less but can and frequently are activated several times a day.

WAPA may use available generating capacity at Glen Canyon Dam and Hoover Dam to support grid reliability and power system operations. Short-duration changes in releases may occur as part of normal power regulation activities. WAPA's ability to supply emergency assistance is limited by available transmission capacity and available generation capability, while the ability to deliver emergency assistance varies on an hourly basis, depending on firm load obligations and available generation from project resources.

Transmission System[8]

The Hoover, Glen Canyon, Parker, and Davis Powerplants are connected to a transmission system. Each facility's generation can affect transmission limitations when lines do not have enough capacity to transmit electricity from the point of generation to the point of demand. Actual transmission refers to the measured flow of power on the line. WAPA operates 17,000 circuit miles of transmission lines.

Power Marketing

WAPA markets long-term firm capacity and energy, short-term, firm capacity and energy, and non-firm energy. Firm power is capacity and energy that are guaranteed to be available to the customer. Loads are made up of firm load, non-firm sales, and interchanges out of the control area. Firm load and capacity obligations include long- and short-term firm sales, Reclamation project use loads, system losses, balancing authority control area regulation, firm load contingency reserves, and scheduled outage assistance. Capacity is reserved to provide regulation, contingency reserves,

[7] Disturbance and emergencies and outage assistance are discussed for context. The alternatives in this Final EIS do not address disturbance, emergencies, or outage assistance and there are no anticipated impacts on these from the alternatives.

[8] Transmission is discussed for context. The alternatives in this Final EIS do not address transmission and there are no anticipated impacts on transmission from the alternatives.

frequency support and response, meet contractual obligations, and participating project capacity. For Glen Canyon Dam, capacity is also reserved to serve Reclamation's irrigation and drainage pumping plant loads before being marketed as long-term firm capacity.

Colorado River Storage Project

In fiscal year 2025, WAPA marketed 4,268 gigawatt hours (GWh) of wholesale CRSP power to approximately 130 entities serving retail customers in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Customers are small to medium-sized municipalities that operate publicly owned electrical systems; irrigation cooperatives and water conservations districts; rural electrical associations or generation and transmission co-operatives who often act as wholesales to these associations; federal facilities such as Air Force bases, universities, and other state agencies, and tribes. Capacity and energy from Glen Canyon Dam are bundled and marketed by WAPA as the Salt Lake City Area Integrated Projects (SLCA/IP). Electricity generated at SLCA/IP facilities in the Upper Colorado Region is marketed by WAPA under statutory criteria in the Reclamation Project Act of 1939, the Flood Control Act of 1944, CRSPA, and the Department of Energy Organization Act of 1977, along with associated marketing plans and contractual obligations. The majority of CRSP power is sold under long-term firm electric service contracts. If WAPA is unable to supply contract amounts of firm capacity or energy from Reclamation hydroelectric resources, it must purchase the deficit from other (primarily non-hydropower) resources for delivery. The expense for this purchase power is shared by all SLCA/IP customers. Reliance on SLCA/IP capacity and energy varies considerably among customers. In general, rural customers are more reliant on hydropower resources as a percentage of their total resource portfolio compared to urban customers.

Tribal Benefit Crediting

Tribes receive hydropower from WAPA, including hydropower from Glen Canyon Dam. Glen Canyon Dam is one component of a larger hydropower system and is included with other powerplants for marketing purposes. Capacity and energy from Glen Canyon Dam are bundled and marketed by WAPA as the SLCA/IP to consumers across Arizona, Colorado, Nebraska, New Mexico, Nevada, Utah and Wyoming. In the 2016 LTEMP Final EIS, tribal populations with the potential to be affected by project management include those who receive annual SLCA/IP allocations. The 2016 LTEMP Final EIS (Reclamation 2016a, Appendix K, Attachment 12) provides a comprehensive list of the annual SLCA/IP allocations to American Indian tribes and benefit information. When originally allocated in 2002, WAPA anticipated serving about 55.7 percent of total tribal electric use in the summer season and 58.8 percent in the winter season. There are 53 tribes or tribal entities that have signed firm electric service contracts with WAPA to receive power from SLCA/IP, which includes power from Glen Canyon Dam. Over the past 20 years, tribal load growth and reductions in hydropower due to drought have reduced that original percentage. There are currently seven tribes or tribal entities that operate electric utilities and receive power deliveries directly from WAPA. The remaining tribes operate under benefit crediting arrangements. Under a benefit crediting arrangement, the tribe's electric service supplier takes delivery of the SLCA/IP allocation and in return gives an economic benefit or payment to the tribe. In other words, the utility receives WAPA power on behalf of the tribe; subsequently, the utility receives the benefit of the power and transfers the economic benefit of the federal hydropower allocation to the tribe. Ideally, arrangements are made with public power utilities in areas that receive an allocation of power from WAPA such as a rural electric cooperative or municipality (however, exceptions apply

for various reasons). Because benefit crediting arrangements are typically a function of MWh provided, a reduction in energy deliveries from WAPA translates directly into a reduced financial benefit to a tribe.

Desert Southwest Region

WAPA markets 10,600 GWh of wholesale Desert Southwest Region power to 80 entities in Arizona, southern California, and southwest Nevada. Capacity and energy from Hoover Dam are bundled and marketed by WAPA as the BCP and capacity and energy from Parker and Davis Dams are bundled and marketed by WAPA as the PDP to consumers in Nevada, Arizona, and California.

The BCP has delivered power to customers for over 80 years. The BCP Post-2017 remarketing effort was created in 2014 to determine power allocations for the Hoover Powerplant that expired in September 2017 (WAPA 2017). The new BCP contracts were signed in October 2016 and now run from 2017-2067. The existing contract delivers power to 46 direct and 74 total allocations including allocations through state agencies in Arizona, Nevada, and Southern California.

Davis Dam provides all 255,000 kW of operating capacity to the PDP and Parker Dam provides 60,000 kW of operating capacity to the PDP and 60,000 kW to the Metropolitan Water District of Southern California (WAPA 2024). The existing PDP sales contract expires in 2028 and a plan for a future remarketing is underway. At present, there are 36 contractors receiving power allocations from the PDP. The electricity produced by the PDP provides electricity to approximately 300,000 people (WAPA 2025c).

Rates

WAPA sets rates for firm electric service from Federal hydropower projects in its marketing territory based on Department of Energy regulations and applicable Federal statutes. Customers pay rates that align specifically with the project they buy power from.

WAPA has a public rate-setting process that includes collaborative planning, a public comment period, and information and comment forums. A *Federal Register* notice announces proposed rates before the comment periods and then another notice is issued with final rates at the end of the process.

Wholesale Rates

WAPA has various wholesale customers including municipal utilities, federal and state public power facilities, and rural electric cooperatives as well as tribal entities. Power rates are established in order for revenues to be sufficient to pay all costs assigned to power within required time periods. Power revenues also pay annual power operation and maintenance, purchased power, transmission service, and interest expenses on Treasury loans used to finance construction of power and transmission projects, and irrigation assistance beyond the ability of the irrigators to repay. CRSP and Lower Colorado Dam's power revenues also must contribute toward salinity control costs under the Basin Salinity Control Act. CRSP power revenue also contributes to construction costs (with interest) of CRSP-participating projects, as well as certain environmental costs as provided under the Grand Canyon Protection Act. Arizona power customers pay a surcharge for Central Arizona Project construction projects and Multispecies Conservation Program costs. Remaining annual revenues are

used to pay off investment costs assigned to power, so that each investment can be paid within the time allowed (Reclamation 1995).

Retail Rates

Retail rates are those paid by end users (residential, commercial, and industrial customers of WAPA's wholesale customers). The retail rates charged by not-for-profit entities normally are set to cover system operation and capital costs. As costs of these individual components change, the retail rates are adjusted to ensure enough revenue is collected to meet the utility's financial obligations.

TA 15.2 Environmental Consequences

This environmental consequences section analyzes the effects of the alternatives on: the minimum power pool for Lake Powell and Lake Mead; the power capacity of the Glen Canyon and Hoover Powerplants; the power generation of the Glen Canyon, Hoover, Davis, and Parker Powerplants; spillway use of Glen Canyon Dam and Hoover Dam; and electricity rates and the market value of the electricity.

The spillway condition and hydropower capacity of the Davis Dam and Parker Dam are not analyzed because Lake Mohave and Lake Havasu reservoirs have historically remained relatively constant, and their elevations are expected to remain so under all alternatives. Both Lake Mohave and Lake Havasu would continue to be operated under a rule curve that provides specific target elevations at the end of each month (refer to **TA 3.1.8**, Davis Dam to Lake Havasu, in **TA-3**, Hydrologic Resources).

TA 15.2.1 Methodology

WAPA's Colorado River Storage Project Python-based model (CRiSPPy) and Reclamation's Colorado River Simulation System (CRSS) model and Decision Making under Deep Uncertainty (DMDU) analysis framework inform the basis for the effects analysis. Refer to **Chapter 3**, **Section 3.2.6**, Decision Making under Deep Uncertainty for additional details on the DMDU framework and **Appendix E**, DMDU Overview and Approach, for an overview of how to interpret the DMDU conditional box plots, robustness of futures, and vulnerability bar plots. The CRSS model models: potential water releases from the dams; reservoir elevations; and power generation for each of the alternatives and the Continued Current Strategies (CCS) Comparative Baseline. Additional information on CRSS model and model assumptions can be found in **Appendix A**, CRSS Model Documentation. The CRiSPPy model was updated to specifically address the scope of this Final EIS. The model covers 34 years of monthly operations (2027–2060) across 400 hydrology conditions with each alternative representing 163,200 model runs. The CRiSPPy model is a hydropower scheduling tool developed by Argonne National Laboratory for WAPA that combines optimization algorithms, data management, and graphical user interface. CRiSPPy model assumptions can be found in the technical report CRiSPPy: An advanced hydropower scheduling tool for the Colorado River Storage Project (Ploussard et al. 2025). The analysis of the impacts of the alternatives on electricity rates (wholesale) and the market value of the electricity for Glen Canyon Dam is based on analysis WAPA and Argonne National Laboratory prepared in the Post-

2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project (Yu et al. 2025).

TA 15.2.2 Impact Analysis Area

The analysis area for Issues 1-4 encompasses the four primary dams in the Colorado River corridor from the full pool elevation of Lake Powell to the Southerly International Boundary: Glen Canyon Dam/Lake Powell reservoir, the Hoover Dam/Lake Mead reservoir, Davis Dam/Lake Mohave reservoir, and Parker Dam/Lake Havasu reservoir. The analysis area for Issue 5 consists of the WAPA retail power customers of Glen Canyon Dam power that are in the states of Arizona, Colorado, Nevada, New Mexico, Nebraska, Utah, and Wyoming.

Assumptions

All action alternatives, except for the Basic Coordination Alternative, incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (refer to **Appendix S**). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

The Lower Basin electrical generation and firm capacity modeling results are direct outputs from the CRSS model. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation. The Glen Canyon Dam electrical generation and firm capacity modeling results are direct outputs from the CRiSPPy model. The modeled firm capacity in a given month is calculated as the largest, or peak, value of the power output modeled by CRiSPPy in that month. For additional information and modeling assumptions, please refer to CRiSPPy: An advanced hydropower scheduling tool for the Colorado River Storage Project (Ploussard et al. 2025). The Glen Canyon Dam rates analysis data was developed by Argonne National Laboratory. Information and modeling assumptions for the rates analysis can be found in the Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project (Yu et al. 2025)

Impact Indicators

- Lake Powell and Lake Mead Reservoir elevations – Reservoir elevations were evaluated in relation to the minimum power pool elevations for Lake Powell and Lake Mead and in relation to Glen Canyon Dam and Hoover Dam infrastructure and safety.
- Firm capacity (MW) – Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates. Firm capacity is measured in MW. This analysis utilizes firm capacity as an indicator rather than physical capacity because it more accurately reflects the actual conditions WAPA and Reclamation use for operational decisions.
- Energy generation (MWh) – The amount of energy created over a certain period, measured in MWhs. Energy generation is dependent on reservoir head and water release volume.
- Spillway releases – spillway releases due to operational activities.
- Electricity rates – The minimum average rate increase amount per major rate increase measured in $/MWhs for customers of Glen Canyon Dam power.
- Market value of electricity – The future market value of electricity generated at Glen Canyon Dam measured in millions of dollars per year.

TA 15.2.3 Issue 1: How do the alternatives impact the frequency at which reservoir elevations drop below minimum power pool at Lake Powell and Lake Mead?

Minimum power pool is the lowest reservoir elevation level at which a hydropower plant can produce power. The frequency at which reservoir elevations drop below minimum power pool for Glen Canyon Dam/Lake Powell reservoir and Hoover Dam/Lake Mead reservoir were measured by calculating the percent of futures in which the elevations of the reservoirs achieve the preferred minimum performance of maintaining elevations at or above 3,490 feet and 950 feet, respectively (refer to **Figure TA 15-10** and **Figure TA 15-12**); and by using vulnerability figures that display conditions that could cause Lake Powell and Lake Mead to drop below these thresholds (3,490 feet and 950 feet respectively), representing undesirable performance when elevations fall below minimum power pool in one or more months (refer to **Figure TA 15-11** and **Figure TA 15-13**).

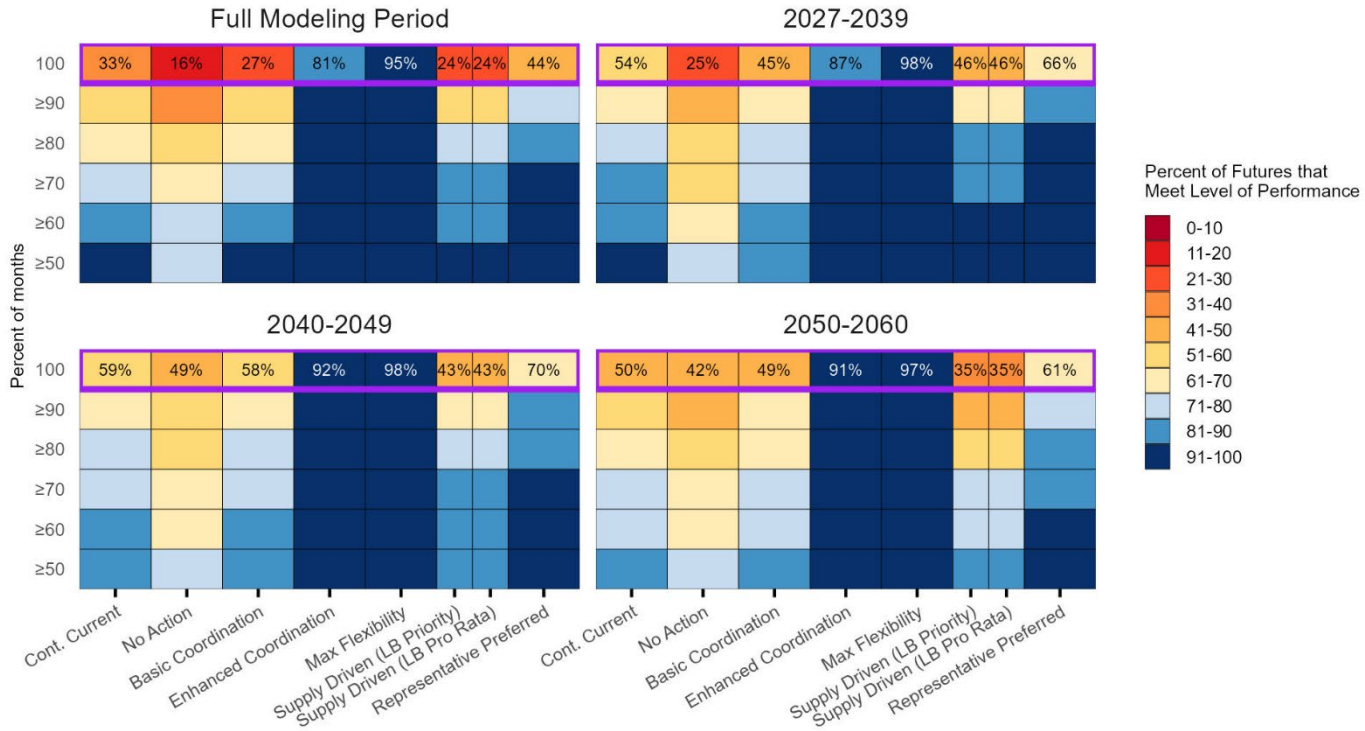
In addition to the importance of elevation 3,490 to hydropower at Lake Powell, there are also infrastructure concerns associated with the uncertainty of extended operations through the river outlet works as the sole means of sustained water releases from Glen Canyon Dam that could compromise the reliability and operational flexibility of Glen Canyon Dam and affect the ability to meet critical downstream water supply needs, as described in **Section 1.8.4.1**.

Figure TA 15-10 below shows the percentage of futures for each alternative (columns) in which Lake Powell elevation is 3,490 feet or above in the percent of months specified by each row. The highlighted row represents the preferred minimum level of performance, which is for elevations to be at least 3,490 feet in all months (i.e., 100 percent of the time). Results are shown for the Full Modeling Period and three subperiods: 2027–2039, 2040–2049, and 2050–2060.

In the Full Modeling Period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in 81 percent and 95 percent of modeled futures, respectively, which is considerably more robust than the other alternatives. The Representative Preferred Alternative meets the preferred minimum performance level in 44 percent of futures, with the third highest robustness score. The No Action, Supply Driven (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches), Basic Coordination Alternatives, and CCS Comparative Baseline are only able to meet the preferred minimum performance at or below 33 percent of futures. Across all subperiods modeled, both Enhanced Coordination and Maximum Operational Flexibility Alternatives meet the preferred minimum performance in greater percentages of futures than the others, never falling below 87 percent of futures. The next best performing is the Representative Preferred Alternative, ranging between 61 to 70 percent of futures across all subperiods.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. Maximum Operational Flexibility (98 percent) and Enhanced Coordination (87 percent) are the most robust alternatives, followed by the Representative Preferred Alternative (66 percent). The No Action Alternative is the least robust (25 percent), and the Basic Coordination Alternative (45 percent), Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative (46 percent), and the CCS Comparative Baseline (54 percent) perform in the middle.

Figure TA 15-10
Lake Powell Power Pool: Robustness.
Percent of futures in which Lake Powell elevation is at least 3,490 feet in the percent of months specified in each row



Note: Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water). This remains true for the following models in this technical appendix.

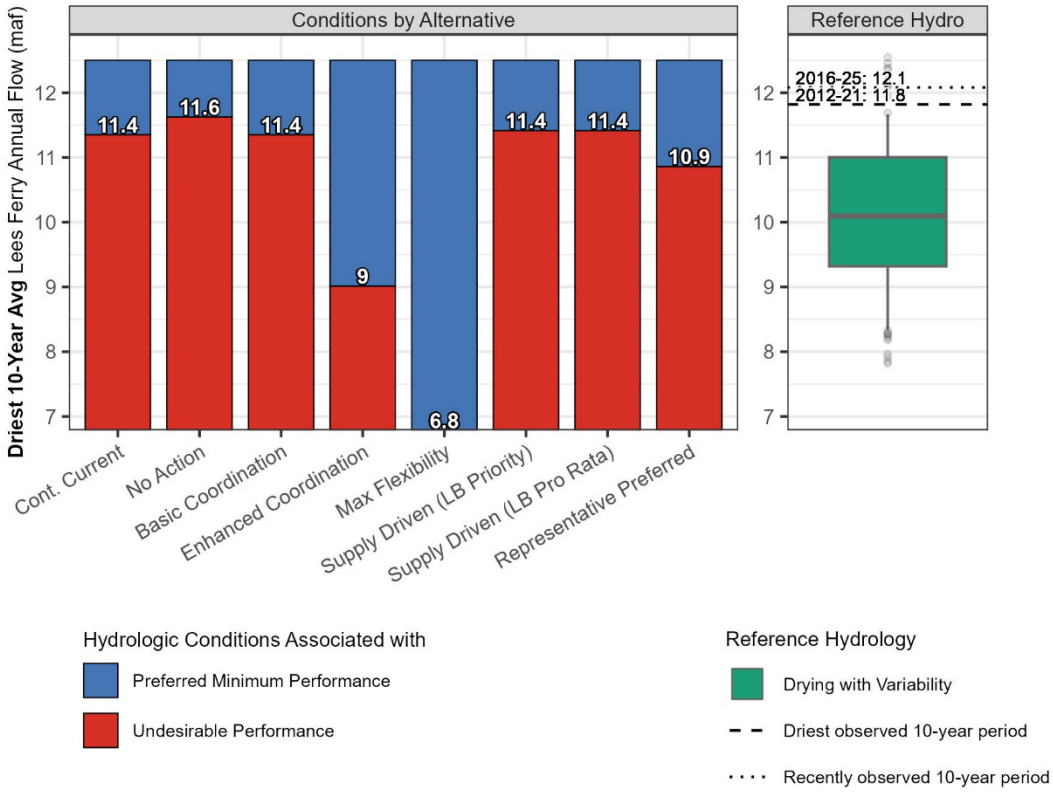
Figure TA 15-11 below shows what flow conditions are likely to cause Lake Powell's elevation to fall below 3,490 feet in any month. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-10** above, which defined a future as successful when an alternative stayed above minimum power pool in 100 percent of months.

For this vulnerability analysis, the driest 10-year average Lees Ferry natural flow was determined to be a skillful predictor of undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The CCS Comparative Baseline, Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would likely be vulnerable to Lake Powell elevation falling below 3,490 feet under a 10-year average Lees Ferry natural flow of 11.4 maf or drier, which is slightly less

vulnerable than the No Action Alternative which is likely to be vulnerable if the 10-year average is 11.6 maf or drier. These conditions are similar to the driest observed 10-year average of 11.8 maf and occur in more than 75 percent of traces in the Drying with Variability Ensemble. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are not likely to be vulnerable to undesirable performance unless the 10-year average flow is much drier than any observed conditions; fewer than 25 percent of traces in the Drying with Variability Ensemble include conditions that would be likely to cause vulnerability in the Enhanced Coordination Alternative, while the Maximum Operational Flexibility Alternative is not vulnerable to any traces in the Drying with Variability Ensemble.

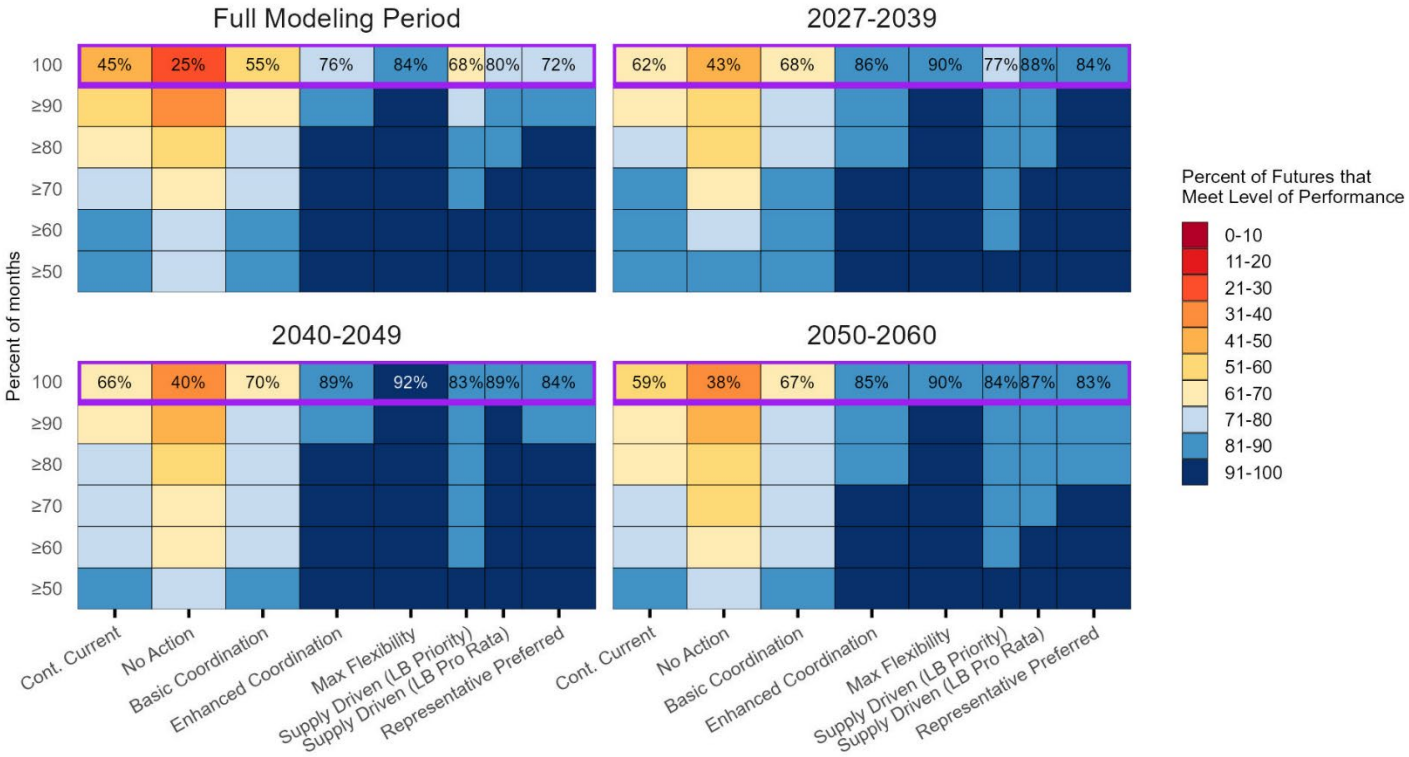
Figure TA 15-11
Lake Powell Power Pool: Vulnerability.
Conditions that Could Cause Lake Powell Elevation Below 3,490 Feet in any Month



Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of Lake Powell elevation falling below 3,490 feet under a 10-year average flow of 10.9 maf. While these conditions have not yet been observed, absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions occur in nearly 75 percent of traces in the Drying with Variability Ensemble, which represents a drier future.

Figure TA 15-12 below shows the percentage of modeled futures in which Lake Mead elevations are maintained at or above 950 feet under each alternative. Results are presented for four modeling periods: the Full Modeling Period, and 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains elevations of 950 feet or above 100 percent of the time.

Figure TA 15-12
Lake Mead Power Pool: Robustness.
Percent of futures in which Lake Mead elevation is at least 950 feet in the percent of months specified in each row



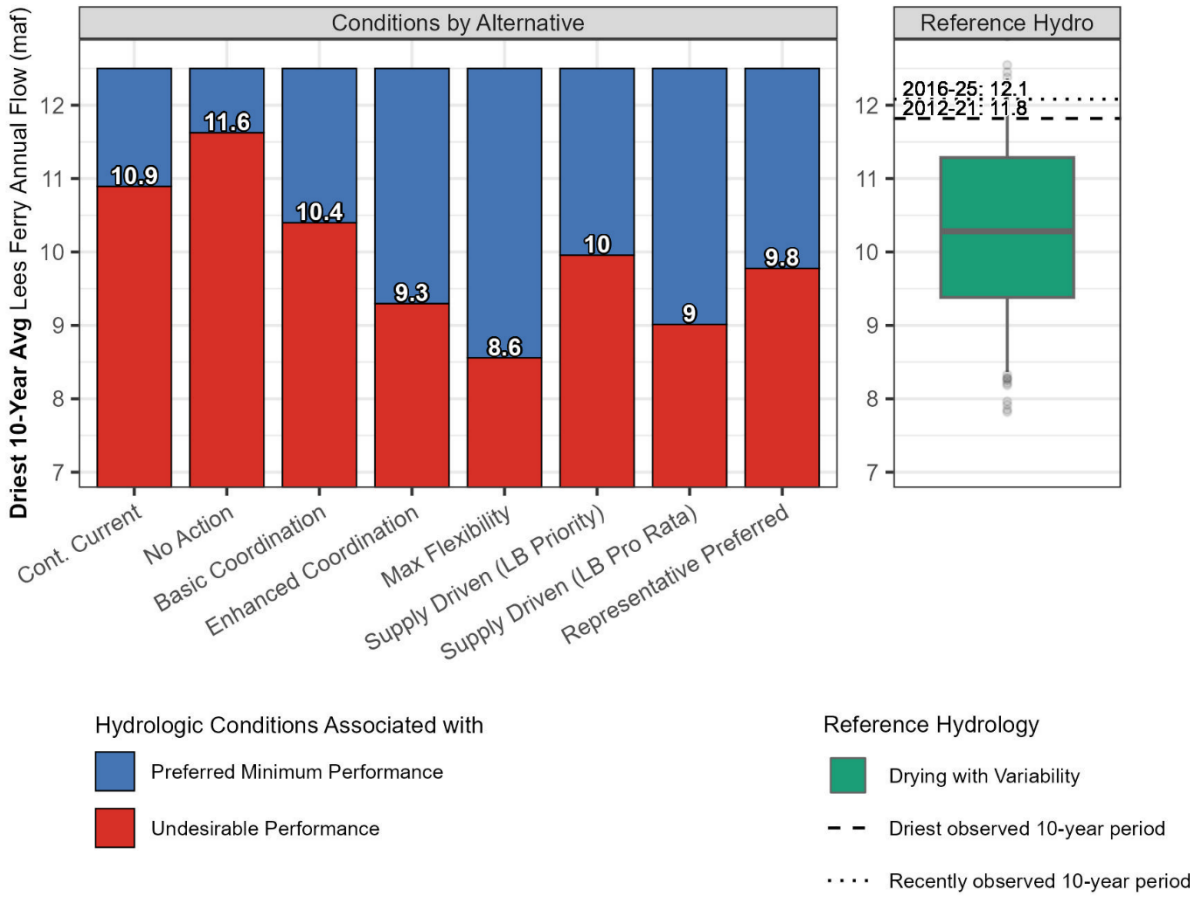
In the Full Modeling Period, the Maximum Operational Flexibility (84 percent), Supply Driven (LB Pro Rata approach) (80 percent), Enhanced Coordination (76 percent), and Representative Preferred (72 percent) Alternatives were fairly robust. The Supply Driven Alternative (LB Priority approach) performed moderately well, meeting the preferred minimum performance in 68 percent of modeled futures. The CCS Comparative Baseline (45 percent), and Basic Coordination (55 percent) and No Action (25 percent) Alternatives did not perform as well as the other alternatives.

Across the subperiods, the Maximum Operational Flexibility, Supply Driven (LB Pro Rata approach), Enhanced Coordination, and Representative Preferred Alternatives meet the preferred minimum performance in 80 to 92 percent of all futures and are considerably more robust than the other alternatives. The CCS Comparative Baseline, Basic Coordination, and No Action Alternatives met the preferred minimum performance in fewer futures.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Maximum Operational Flexibility, Supply Driven (LB Pro Rata approach), Enhanced Coordination, and Representative Preferred Alternatives meet the preferred minimum performance in 84 percent or more of futures, followed closely by the Supply Driven Alternative (LB Priority approach) (77 percent). The Basic Coordination Alternative (68 percent), CCS Comparative Baseline (62 percent), and No Action Alternative (43 percent) are less robust.

Figure TA 15-13 below shows what flow conditions are likely to cause the Lake Mead elevation to fall below 950 feet in any month, resulting in reduced or lost hydropower generation. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-12** above, which defined a future as successful when an alternative maintained Lake Mead elevation above 950 feet 100 percent of the time.

Figure TA 15-13
Lake Mead Power Pool: Vulnerability.
Conditions that Could Cause Lake Mead Elevation Below 950 Feet in any Month



For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be a skillful predictor of undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow

from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison. The Drying with Variability median value is 10.3 maf.

The No Action Alternative (11.6 maf) and CCS Comparative Baseline (10.9 maf) are most vulnerable to undesirable performance (nearly 75 percent or more traces in the Drying with Variability ensemble included these conditions or worse). In contrast, the Maximum Operational Flexibility (8.6 maf), Supply Driven (LB Pro Rata approach) (9 maf), and Enhanced Coordination (9.3 maf) Alternatives reach undesirable performance as hydrologic conditions become drier (around 25 percent or less of the Drying with Variability traces included these conditions or worse) indicating lower vulnerability. The Representative Preferred (9.8 maf) and Supply Driven (LB Priority approach) (10 maf) Alternatives are in the middle, being vulnerable in 25 to 50 percent of traces in the Drying with Variability Ensemble. The driest observed 10-year average Lees Ferry flow in the historical record is 11.8 maf; therefore, vulnerability thresholds for all alternatives are below what has already occurred.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of Lake Mead elevation falling below 950 feet under a 10-year average flow of 9.8 maf. This alternative may or may not be vulnerable in the next 10 years because these conditions have not yet been observed but occur in more than 25 percent and fewer than 50 percent of traces in the Drying with Variability Ensemble, which represents a drier future.

Figure TA 15-14 below reports the percent of modeled futures in which each alternative maintains Lake Mead elevations at or above 1,035 feet in the percentage of time specified in each row. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains elevations at or above 1,035 feet at least 90 percent or more of the time. At an elevation of 1,035 feet, Hoover's high-head units can operate, marking the minimum elevation for viable high-head turbine operation. Total plant capacity at 1,035 feet is substantially reduced (approximately 382 MW), and additional capacity increases with higher elevations as head improves and more units become usable. Four modeling periods are shown: the Full Modeling Period, 2027-2039, 2040-2049, and 2050-2060.

In the Full Modeling Period, the percentage of futures that meets the preferred minimum performance level is highest under the Supply Driven Alternative (LB Pro Rata approach) at 55 percent, followed by the Enhanced Coordination Alternative at 46 percent. The Supply Driven (LB Priority approach) (43 percent), Maximum Operational Flexibility (36 percent), and the Representative Preferred (32 percent) Alternatives outperform the CCS Comparative Baseline (19 percent), and Basic Coordination (26 percent) and No Action (9 percent) Alternatives. The CCS Comparative Baseline, Basic Coordination and No Action Alternatives are the least robust with respect to maintaining the Lake Mead elevation required for high-head turbine performance.

Figure TA 15-14
Lake Mead High-Head Turbines: Robustness.
Percent of futures in which Lake Mead elevation is at least 1,035 feet in the percent of months specified in each row

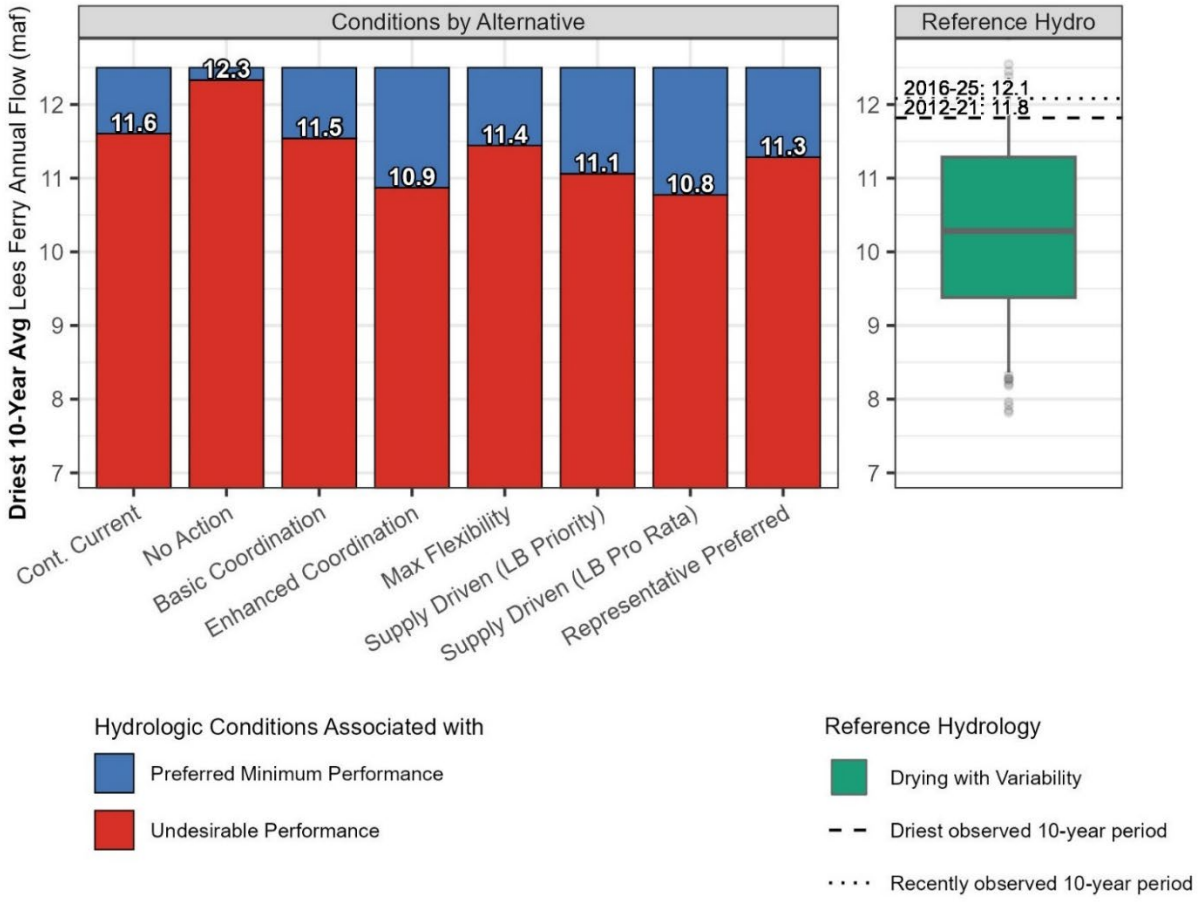


For the first sub-period (2027-2039), all alternatives achieved the preferred minimum performance in 18 to 36 percent of futures. No Action Alternative was the least robust, meeting the preferred performance in 7 percent of futures. In the second subperiod (2040-2049), the Supply Driven (LB Pro Rata approach) (80 percent), Supply Driven (LB Priority approach) (73 percent), Enhanced Coordination (73 percent), and Maximum Operational Flexibility (72 percent) Alternatives performed significantly better than the previous decade. In the final subperiod (2050-2060), the Supply Driven Alternative (LB Pro Rata approach) meets the preferred minimum performance in 82 percent of futures. The lowest performing alternative across all subperiods was the No Action Alternative, followed by the CCS Comparative Baseline.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Supply Driven Alternative (LB Pro Rata approach) is the most robust (36 percent), followed by the Supply Driven (LB Priority approach) (26 percent) and Representative Preferred (25 percent) Alternatives. The remaining action alternatives and CCS Comparative Baseline range from 18 to 23 percent. The No Action Alternative is the least robust at 7 percent.

Figure TA 15-15 below shows the flow conditions associated with Lake Mead elevation falling below 1,035 feet in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-14** above, which defined a future as successful when an alternative maintains Lake Mead elevations at or above 1,035 feet at least 90 percent of the time.

Figure TA 15-15
Lake Mead Power Pool: Vulnerability.
Conditions that could cause Lake Mead elevation to fall below 1,035 feet in more than 10 percent of months



For this vulnerability analysis, the driest 10-year average Lees Ferry annual flow was determined to be a skillful predictor of undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The driest observed 10-year average flow from 2012-2021 (11.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison. The Drying with Variability median value is 10.3 maf.

The No Action Alternative (12.3 maf) is vulnerable to conditions wetter than the recent 10-year average of 12.1 maf, making it the most vulnerable alternative. Following are the CCS Comparative Baseline (11.6 maf), and Basic Coordination (11.5 maf), Maximum Operational Flexibility (11.4 maf), and Representative Preferred (11.3 maf) Alternatives which are vulnerable to hydrological conditions that occur in 75 percent or more of the Drying with Variability traces. Enhanced Coordination (10.9 maf), Supply Driven (LB Priority approach) (11.1 maf), and Supply Driven (LB Pro Rata approach) (10.8 maf) Alternatives were vulnerable to hydrological conditions that occur in 50 to 75 percent of the Drying with Variability traces.

The driest observed 10-year average Lees Ferry flow in the historical record is approximately 11.8 maf; except for the No Action Alternative, vulnerability thresholds are below what has already occurred.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to Lake Mead elevation falling below 1,035 feet in more than 10 percent of months under a 10-year average flow of 11.3 maf. Absent additional action, this alternative is reasonably likely to be vulnerable in the next 10 years because these conditions are close to what has already occurred and they occur in about 75 percent of traces in the Drying with Variability Ensemble.

Summary of Issue 1 Impacts

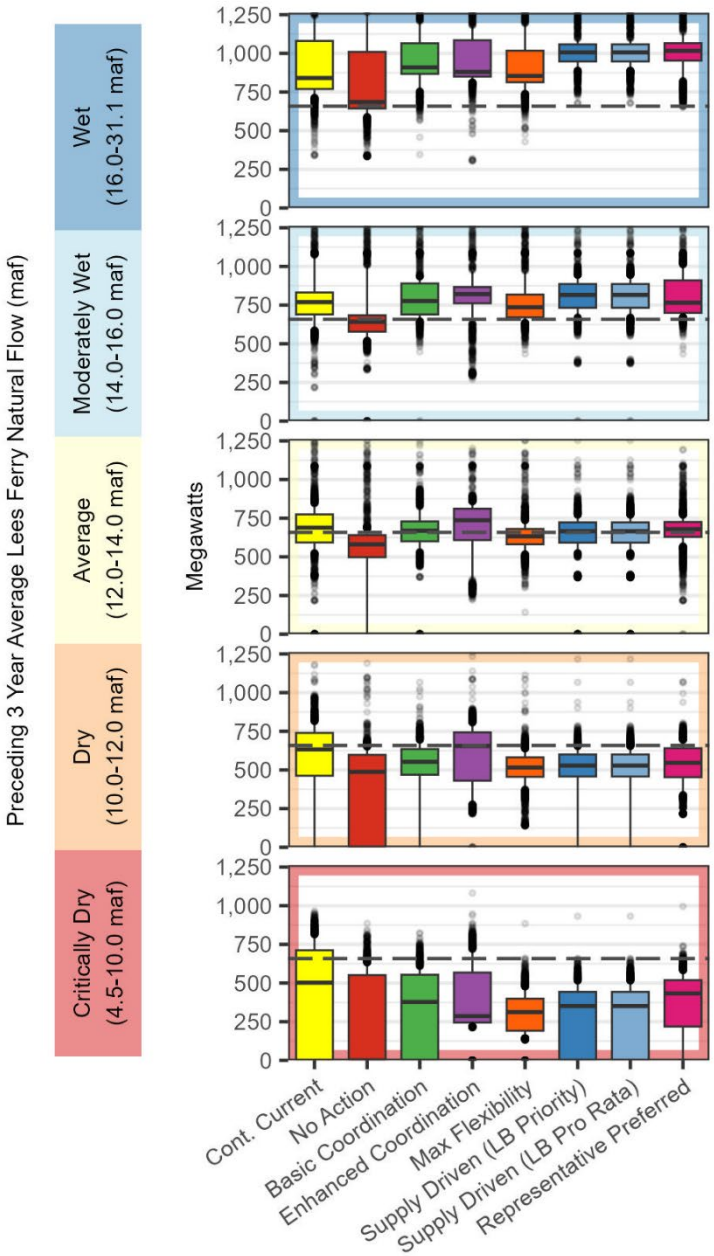
Across both Lake Powell and Lake Mead, the Maximum Operational Flexibility and Enhanced Coordination Alternatives consistently show higher robustness, maintaining elevations above minimum power pool in the greatest percentages of modeled futures, and are less vulnerable to undesirable performance under drier hydrological conditions. In contrast, the CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives exhibit greater vulnerability, with higher frequencies of dropping below minimum power pool and broader exposure to low-elevation conditions, especially under drier hydrology. At Lake Powell, Maximum Operational Flexibility and Enhanced Coordination Alternatives perform best, maintaining preferred conditions in 81 to 95 percent of futures over the full modeling period and showing lower vulnerability (between 6.8–9 maf), while other alternatives reach undesirable performances. The Representative Preferred Alternative is less protective of elevation 3,490 feet than the Enhanced Coordination and Maximum Operational Flexibility Alternatives, but more protective than the other alternatives and CCS Comparative Baseline. Similarly, at Lake Mead, Maximum Operational Flexibility, Enhanced Coordination, Supply Driven (LB Pro Rata approach), and Representative Preferred Alternatives demonstrate stronger performance (72 to 84 percent robustness), whereas the No Action Alternative and CCS Comparative Baseline are the least robust and most vulnerable, indicating a higher likelihood of dropping below minimum power pool under a wider range of hydrologic conditions.

TA 15.2.4 Issue 2: How would the alternatives impact the firm capacity of the Glen Canyon and Hoover Powerplants?

Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates. Firm capacity is measured in MW. This section will consider how the different alternatives impact the firm capacities of the hydropower plants at the Glen Canyon Dam and Hoover Dam.

Figure TA 15-16 below shows the firm capacity of Glen Canyon Dam across five different potential flow categories (Wet [16.0-31.1 maf], Moderately Wet [14.0-16.0 maf], Average [12.0-14.0 maf], Dry [10.0-12.0 maf], and Critically Dry [4.5-10.0 maf]) defined by the preceding 3-year average of Lees Ferry natural flow using August as the flow month. Reclamation used the estimated capacity for the month of August as it corresponds to peak energy demand and typically reflects the maximum available generating capacity. The dashed horizontal line represents the historical average firm capacity (658.3 MW, based on August 2016–2025 conditions). The bold center line of each box represents the median value, the box bounds represent the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Figure TA 15-16
Glen Canyon August Power Capacity: Box Plots



Across most alternatives, firm capacity is highest under the Wet Flow Category, with higher median values and relatively narrower interquartile ranges, indicating strong and consistent performance under wetter hydrologic conditions. The Representative Preferred Alternative performs best with a median of 1,016 MW. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative had a median 1,006 MW and similar variability to the Representative Preferred Alternative. The Enhanced Coordination, Maximum Operational Flexibility, and Basic Coordination Alternatives, and the CCS Comparative Baseline had median firm capacities ranging from 841 to 909

MW. The No Action Alternative had the lowest median at 685 MW, just above the historical average firm capacity from August 2016–2025 of 658.3 MW.

In the Moderately Wet Flow Category, the Enhanced Coordination, Basic Coordination, Representative Preferred, Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, and the CCS Comparative Baseline generally exhibit higher median firm capacity and more favorable distributions than the Maximum Operational Flexibility and No Action Alternatives, which have lower medians.

Under the Average Flow Category, the Enhanced Coordination Alternative has the highest median value, followed closely by the CCS Comparative Baseline while the No Action Alternative has the lowest median indicating reduced performance. The remaining action alternatives cluster around the historical average firm capacity with similar median values and comparable interquartile ranges, suggesting similar levels of firm capacity under average hydrological conditions.

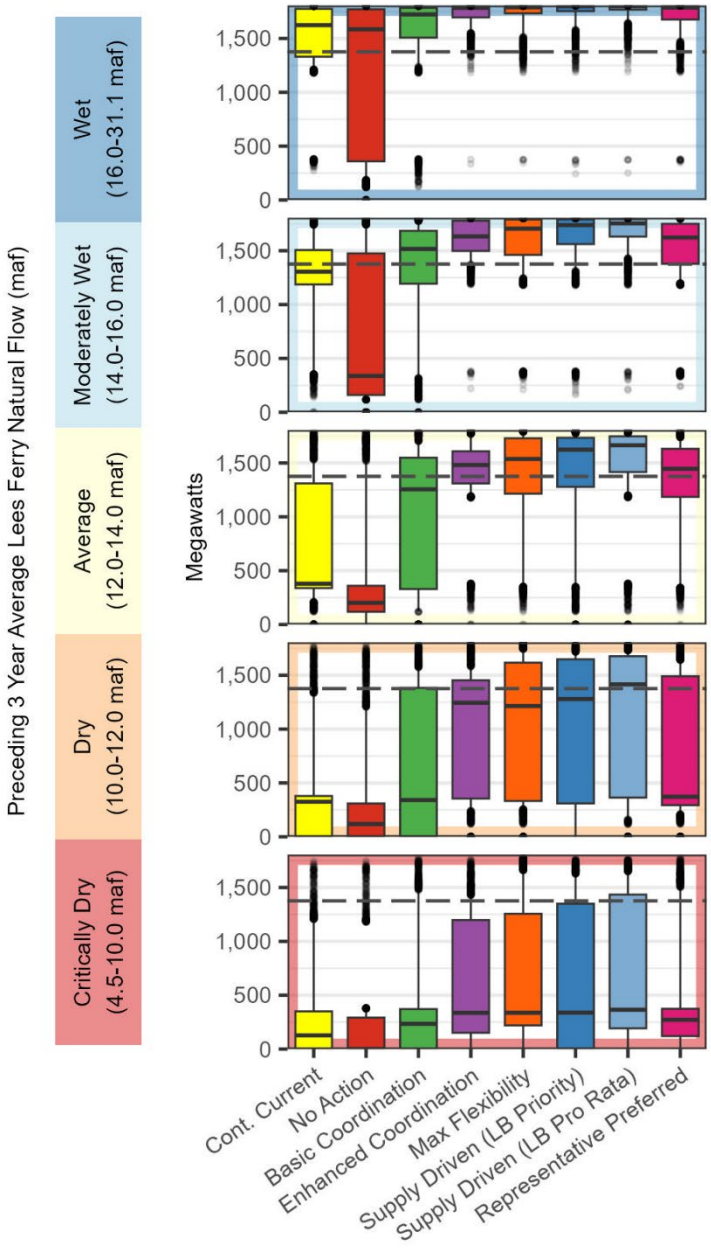
In the Dry Flow Category, median value declines across all alternatives and variability increases, reflecting heightened sensitivity to hydrologic stress. The Enhanced Coordination Alternative exhibits the highest median value in this category, followed by the CCS Comparative Baseline. While the other alternatives have lower medians, their interquartile ranges are narrower, indicating less variable firm capacities. Under dry conditions the No Action Alternative has the lowest median and a firm capacity of 0 MW in at least 25 percent of years.

Under the Critically Dry Flow Category, the CCS Comparative Baseline, and No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have at least 25 percents of years with 0 MW of firm capacity, indicating a high likelihood of undesirable performance under the driest conditions. These results highlight that alternatives emphasizing coordination and flexibility generally maintain higher medians and reduced variability, while less coordinated approaches are more susceptible to firm capacity loss as hydrologic conditions deteriorate.

In the Dry Flow Category, the Representative Preferred Alternative has a median August power capacity of 546 MW and an interquartile range (187 MW) that is near the middle of all alternatives. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median capacity of 433 MW. With an interquartile range of 300 MW, the Representative Preferred Alternative is less variable than all alternatives, except the Maximum Operational Flexibility Alternative.

Figure TA 15-17 below shows the August firm capacity of Hoover Dam across five different potential flow categories (Wet [16.0-31.1 maf], Moderately Wet [14.0-16.0 maf], Average [12.0-14.0 maf], Dry [10.0-12.0 maf], and Critically Dry [4.5-10.0 maf]) defined by the preceding 3-year average of Lees Ferry natural flow. Reclamation used the estimated capacity for the month of August as it corresponds to peak energy demand and typically reflects the maximum available generating capacity. The dashed horizontal line represents the historical average firm capacity (1,376 MW, the average firm capacity between August 2016 to August 2025 based on historical data). The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Figure TA 15-17
Hoover August Power Capacity: Box Plots



Under the Wet Flow Category, most alternatives show relatively high firm capacity with narrow interquartile ranges and similar medians, indicating stable capacity under wetter conditions. The exception in this category is the No Action Alternative which has a similar median to other alternatives (1585 MW) but much higher variability than the other alternatives with an interquartile range of 1412 MW.

In the Moderately Wet Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches), Basic Coordination, Enhanced Coordination, Representative Preferred, and Maximum Operational Flexibility Alternatives generally have median power capacities higher than the historical

average value and relatively narrow interquartile ranges. The CCS Comparative Baseline median (1,305 MW) fell slightly below the historical average firm power capacity. The No Action Alternative had the widest range of variability and the median firm capacity (337 MW) was well below the other alternatives.

Under the Average Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative had the highest median firm capacities (1,624 and 1,664 MW respectively). The Maximum Operational Flexibility and Enhanced Coordination Alternatives had similar medians but the Enhanced Coordination Alternative was less variable than Supply Driven or Maximum Operational Flexibility. The Representative Preferred Alternative has a median firm capacity (1,446 MW) slightly above the historical average and similar variability to preceding alternatives. The Basic Coordination, and No Action Alternatives, and the CCS Comparative Baseline performed considerably worse than the other alternatives with lower median firm capacities and greater variability.

Under the Dry Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative had the highest median firm capacities, followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives. The Representative Preferred Alternative had a much lower median firm capacity (372 MW) but similar variability to the preceding alternatives. The CCS Comparative Baseline and No Action and Basic Coordination Alternatives performed the worst with power capacity reaching zero in more than 25 percent of years.

In the Critically Dry Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches), Maximum Operational Flexibility, and Enhanced Coordination Alternatives experienced wide variability for firm capacity but had median firm capacities around 350 MW. The CCS Comparative Baseline, and No Action, and Basic Coordination Alternatives show the lowest medians and the potential for zero capacity in more than 25 percent of years under the Critically Dry Flow Category.

In the Dry Flow Category, the Representative Preferred Alternative has a median firm capacity of 372 MW with an interquartile range of 1,197 MW. The median of the Representative Preferred Alternative is lower than the other action alternatives but the variability is similar. In the Critically Dry Flow Category, the Representative Preferred Alternative has a median firm capacity (271 MW) that is similar to the other action alternatives. With an interquartile range of 253 MW, the Representative Preferred Alternative is the least variable of all action alternatives.

Summary of Issue 2 Impacts

The firm capacity at Glen Canyon Dam under the Wet Flow Category is the highest under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative. In the Moderately Wet Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) and Enhanced Coordination Alternatives performed with the highest firm capacity. Under Average and Dry Flow Category, the Enhanced Coordination Alternative had the highest median firm capacity. In the Critically Dry Flow Category, the CCS Comparative Baseline had a wide range of variability, with the highest 75th percentile exceeding the historical average firm capacity, and the 25th percentile falling

to 0 MW. Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives 25th percentiles did not fall to 0 MW like that of the other alternatives.

For the Hoover Powerplant, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative provided the highest firm capacities across all flow categories. Considered collectively, the Maximum Operational Flexibility Alternative leads to relatively high firm capacity for both the Glen Canyon Powerplant and the Hoover Powerplant. Although the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative provides high firm capacity, they have a wide interquartile variability indicating less reliable performance under drier conditions. The CCS Comparative Baseline, Basic Coordination and No Action Alternatives performed the worst across all flow categories, with lower median values and 25th percentiles falling to 0 MW in the Dry and Critically Dry Categories. The Representative Preferred Alternative outperforms the CCS Comparative Baseline, No Action Alternative, and Basic Coordination Alternative, but has a lower median capacity than the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, across all flow categories.

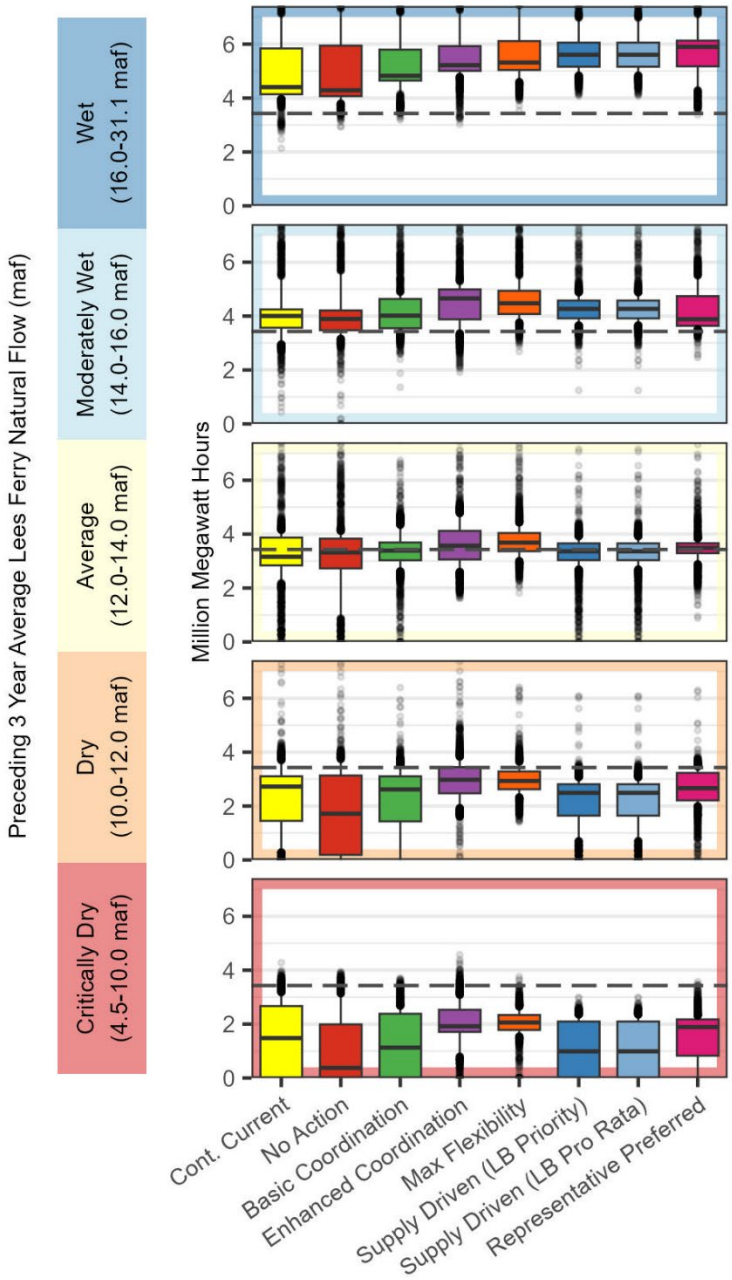
TA 15.2.5 Issue 3: How would the alternatives impact the energy generation of the Glen Canyon, Hoover, Davis, and Parker Powerplants?

Energy generation is the amount of energy created over a certain period, measured in MWhs. Energy generation is dependent on reservoir head and water release volume. The model inputs used to develop the figures in the energy generations analysis simulated releases and lake reservoir elevations to calculate estimated energy generation. **Figure TA 15-18**, **Figure TA 15-19**, **Figure TA 15-20**, and **Figure TA 15-21** illustrate the power generation response of Glen Canyon, Hoover, Davis, and Parker Powerplants, respectively. The box plots illustrate how the alternatives respond during different hydrologic conditions that are based on the preceding 3-year average of Lees Ferry natural flow. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Figure TA 15-18 below shows that under the Wet and Moderately Wet Flow Categories at Glen Canyon Dam, the Supply Driven (both LB Priority [5.6 and 4.3 million MWhs] and LB Pro Rata [5.6 and 4.3 million MWhs] approaches), Maximum Operational Flexibility (5.3 and 4.8 million MWhs), and Enhanced Coordination (5.2 and 4.7 million MWhs) Alternatives, resulted in slightly higher median energy generation values than the other alternatives. The Representative Preferred Alternative performs best under the Wet Flow Category at 5.9 million MWhs but worst under the Moderately Wet Category at 3.9 million MWhs. All alternatives performed above the historical average energy generation of 3.4 million MWhs (2016-2025) in both categories.

Under the Average Flow Category, the Maximum Operational Flexibility (3.7 million MWhs) and Enhanced Coordination (3.6 million MWhs) Alternatives performed slightly above the historical average energy generation value. The median energy generation for the other alternatives remain near the historical average energy generation of approximately 3.4 million MWhs.

Figure TA 15-18
Water Year Glen Canyon Energy Generation: Box Plots



Under the Dry Flow Category, the Maximum Operational Flexibility (2.9 million MWhs) and Enhanced Coordination (2.9 million MWhs) Alternatives have the highest median energy generation and lowest variability of all alternatives. CCS Comparative Baseline, and the No Action, and Basic Coordination Alternatives have greater variability in energy generation than the other alternatives. Under the No Action Alternative energy generation falls to 0 million MWhs in almost 25 percent of years. The No Action Alternative had the lowest median energy generation value of 1.7 million MWhs.

Under the Critically Dry Flow Category, the Maximum Operational Flexibility (2.1 million MWhs), Enhanced Coordination (1.9 million MWhs), and Representative Preferred (1.9 million MWhs) Alternatives continue to show the highest median energy generation values. Energy generation under the CCS Comparative Baseline (1.5 million MWhs), No Action (0.4 million MWhs), Basic Coordination (1.1 million MWhs), and Supply Driven (LB Priority [0.9 million MWhs] and LB Pro Rata [0.9 million MWhs] approaches) Alternatives fall to 0 million MWhs in at least 25 percent of years and have median values never exceeding 1.7 million MWhs.

The Representative Preferred Alternative in the Dry (2.7 million MWhs) and Critically Dry (1.9 million MWhs) Categories experienced higher median values.

Figure TA 15-19 below shows for the Hoover Powerplant, under the Wet and Moderately Wet Flow Categories, the Maximum Operational Flexibility Alternative (4.6 and 3.6 million MWhs), the Supply Driven (both LB Priority [4.9 and 3.6 million MWhs] and LB Pro Rata [5.0 and 3.9 million MWhs] approaches), Representative Preferred (4.6 and 3.5 million MWhs), and the Enhanced Coordination (4.5 and 3.7 million MWhs) Alternatives generally produce the highest median energy generation. The other alternatives perform similarly, except that energy generation under the No Action Alternative falls below the historical average of 3.3 million MWhs (2016-2025) in over 25 percent of years in the Wet Flow Category.

Under the Average Flow Category, the Supply Driven (both LB Priority [3.2 million MWhs] and LB Pro Rata [3.3 million MWhs] approaches) Alternative had the overall highest median energy generation, like the historical average of 3.3 million MWhs (2016-2025). All other action alternatives and the CCS Comparative Baseline had similar median values and are characterized by relatively small interquartile ranges. The No Action Alternative has the greatest interquartile variability and produces the lowest level of median energy generation at 1.9 million MWhs.

In the Dry Flow Category, median energy generation falls below the historical average energy generation for all alternatives. Variability increases markedly over the Dry Flow Category for the CCS Comparative Baseline (2.5 million MWhs), No Action (0.9 million MWhs), and Basic Coordination (2.6 million MWhs) Alternatives. Energy generation reaches 0 million MWhs in more than 25 percent of years under the No Action Alternative.

Under the Critically Dry Flow Category, median energy generation decreased considerably for the CCS Comparative Baseline (0.9 million MWhs) and No Action Alternative. Energy generation fell to 0 million MWhs in more than 50 percent of the time for the No Action Alternative. The median energy generation for the other alternatives was similar to the Dry Flow Category; however, performance was more variable (wider interquartile range) for the Enhanced Coordination, Supply Driven (LB Priority approach), and Representative Preferred Alternatives.

The Representative Preferred Alternative under Dry (2.6 million MWhs) and Critically Dry (1.0 million MWhs) Categories had relatively high median values. 25 percent of years fall to 1 million MWhs or less under the Critically Dry Flow Category.

Figure TA 15-19
Water Year Hoover Energy Generation: Box Plots

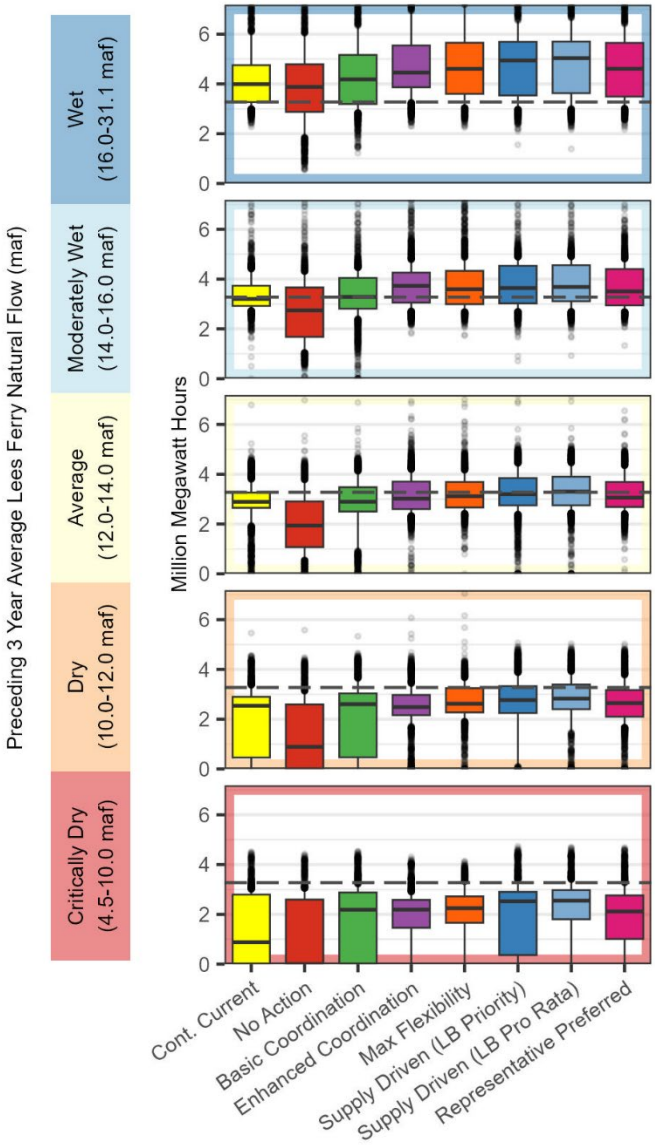
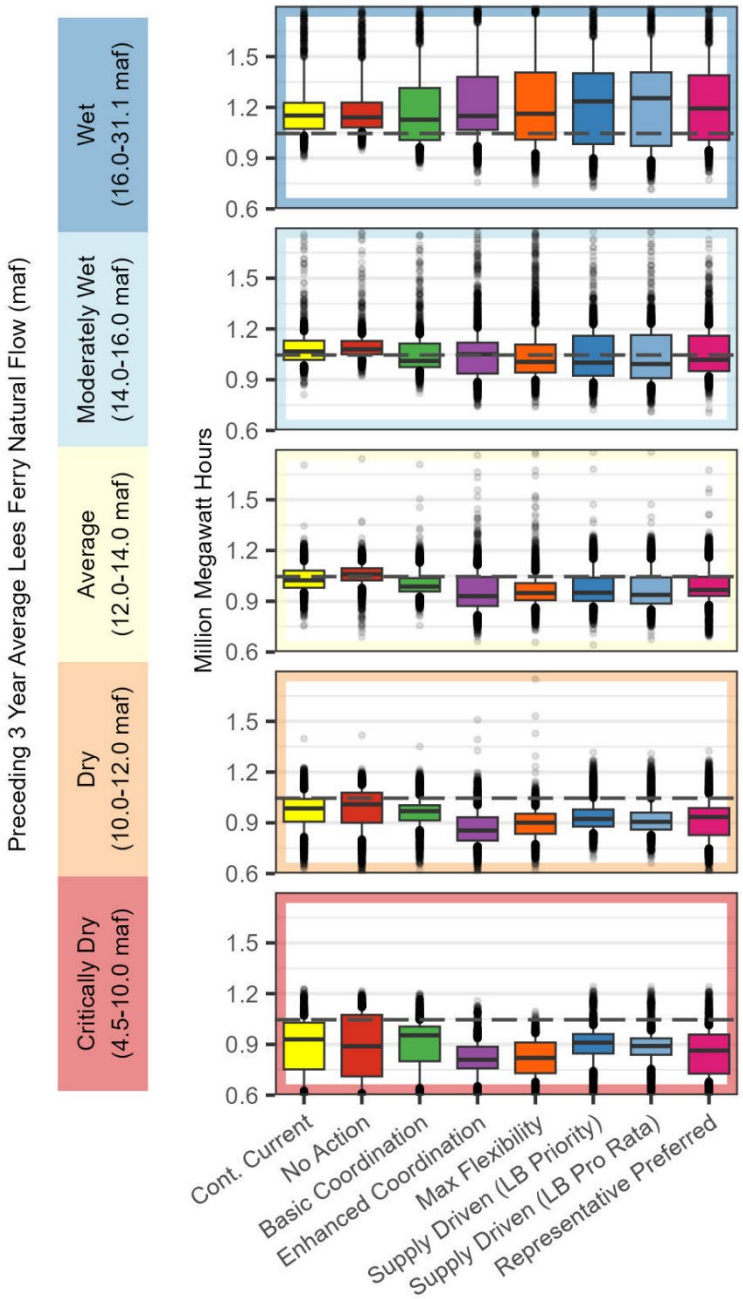


Figure TA 15-20 below shows that for the Davis Powerplant under the Wet Flow Category, the Supply Driven (both LB Priority [1.3 million MWhs] and LB Pro Rata [1.3 million MWhs] approaches) Alternative produces the highest median value, with the 25th percentile falling below the historical average value of 1.0 million MWhs and the 75th percentile at 1.4 million MWhs. All other alternatives performed similarly, with median energy generation near 1.1 million MWhs, but CCS Comparative Baseline and No Action exhibiting the narrowest interquartile ranges, indicating the lowest variability in annual generation value compared to the other alternatives.

Under the Moderately Wet and Average Flow Categories, variability decreases and all alternatives result in median energy generation values near or below the Davis Dam historical average of 1.0 million MWhs. The No Action Alternative (1.1 million MWhs) and CCS Comparative Baseline (1.0

million MWhs) median values perform best in these flow categories and, similar to the Wet Flow Category, have some of the lowest variability in annual generation values.

Figure TA 15-20
Water Year Davis Energy Generation: Box Plots



Under the Dry Flow Category, the CCS Comparative Baseline (0.9 million MWhs) and No Action Alternative (1.0 million MWhs) have slightly higher median energy generation values than the other alternatives. These alternatives begin to show greater interquartile variability in drier flow conditions. The Enhanced Coordination Alternative (0.8 million MWhs) yields the lowest median energy

generation value among all alternatives. In the Critically Dry Flow Category, all alternatives perform similarly to the Dry Flow Category. Interquartile variability of energy generation increases for all alternatives, and all but the No Action Alternative falls below the historical average of 1.0 million MWhs in 75 percent or more of years.

The Representative Preferred Alternative under Dry (0.9 million MWhs) and Critically Dry (0.8 million MWhs) Categories had relatively high median values.

Figure TA 15-21 shows that for the Parker Powerplant, under the Wet Flow Category, the Supply Driven (both LB Priority [0.46 million MWhs] and LB Pro Rata [0.47 million MWhs] approaches) Alternative have the highest levels of median energy generation value and above the 2016-2025 historical average (0.42 million MWhs). The Supply Driven Alternative (LB Pro Rata approach) displays a lower 25th percentile of 0.39 million MWhs. The other alternatives have similar median energy generation values, just above the historical average with the CCS Comparative Baseline and No Action Alternative exhibiting the narrowest interquartile variability.

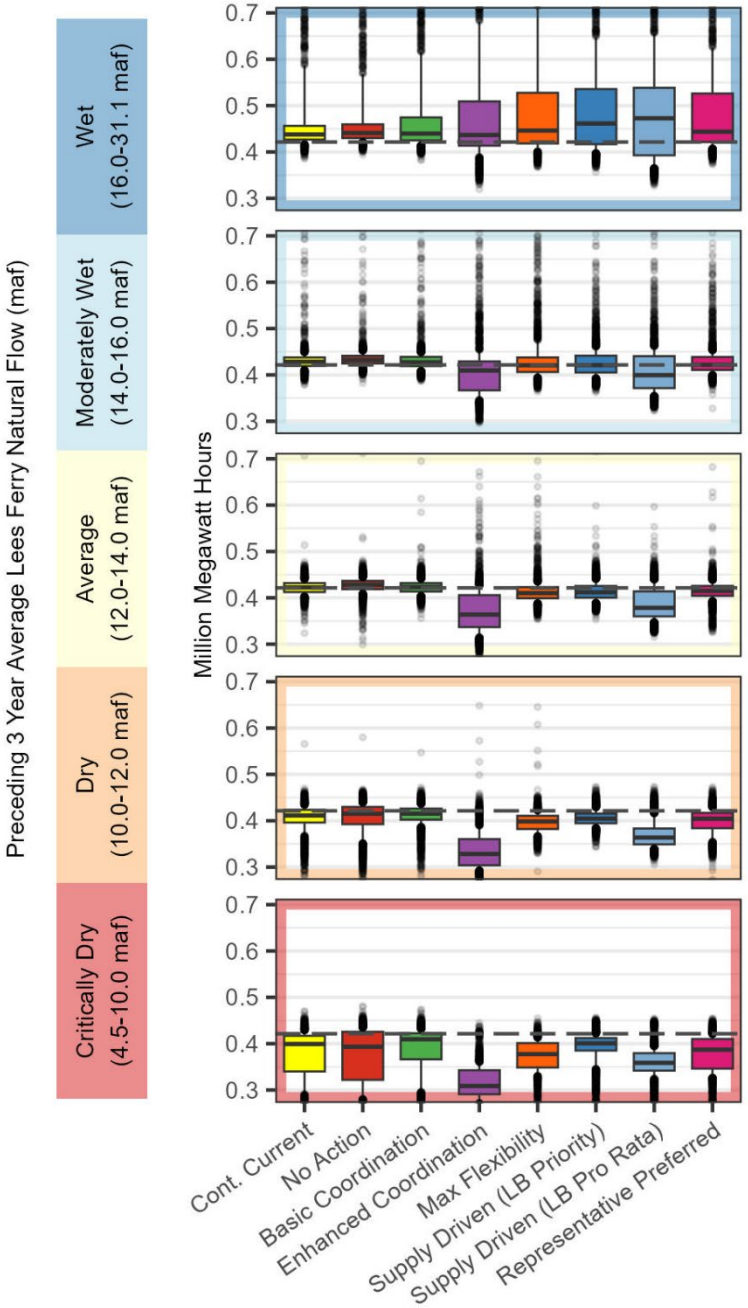
Under the Moderately Wet Flow Category, most alternatives produce energy generation at or near the historical average level. The Supply Driven (LB Pro Rata approach) and Enhanced Coordination Alternatives show relatively wider interquartile ranges indicating more variable energy generation and result in median energy generation valued at just below the historical average.

Under the Average and Dry Flow Categories, all alternatives, other than the Supply Driven (LB Pro Rata approach) and Enhanced Coordination Alternatives generally exhibit narrow interquartile variability and similar median energy generation values, ranging between 0.40 to 0.42 MWhs. The Supply Driven (LB Pro Rata approach) (0.36 million MWhs) and Enhanced Coordination (0.33 million MWhs) Alternatives resulted in a much wider interquartile ranges and a lower median value, indicating these alternatives are more sensitive to drier flow conditions than the others.

Median energy generation continues to decrease in the Critically Dry Flow Category with about 75th percent or more years for all alternatives falling below the historical average. The relative performance between Alternatives is similar to the Average and Dry Flow Categories. The most notable difference is the wider interquartile ranges for all alternatives indicating increased vulnerability to low generation outcomes under the driest conditions.

The Representative Preferred Alternative under Dry (0.4 million MWhs) and Critically Dry (0.39 million MWhs) Categories had relatively high median values.

Figure TA 15-21
Water Year Parker Energy Generation: Box Plots



Summary of Issue 3 Impacts

Energy generation at each of the powerplants responds differently under each of the alternatives. Under wetter conditions, the Glen Canyon Powerplant would have the highest energy generation under the Supply Driven (both LB Priority and LB Pro Rata approaches), Enhanced Coordination, and Maximum Operational Flexibility Alternatives. As conditions become drier, the Representative Preferred and Maximum Operational Flexibility Alternatives remain the most robust, while other

alternatives exhibit greater variability and increased risk of decreased energy generation under critically dry conditions. The Hoover Powerplant would produce the highest amounts of energy under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative in all five flow categories. The Davis Powerplant would have the highest power production under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative under the Wet Flow Category. Under the Moderately Wet to Critically Dry Flow Categories, the No Action Alternative, followed by the CCS Comparative Baseline, generally produced the most energy generation. The Parker Powerplant would produce the most power under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative under the Wet Flow Category. As conditions become drier, the alternatives (with the exceptions of Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives) have similar median values.

TA 15.2.6 Issue 4: How would the alternatives impact spillway use?

Spillway infrastructure is affected by reservoir elevation, particularly high elevations, which vary greatly between alternatives. High reservoir elevations, for extended durations, pose a risk to spillway infrastructure. Keeping the reservoir water level below the spillway crest minimizes spillway drum gate use and spillway use, preserves the water supply, maintains flood storage capacity, and reduces wear and tear on spillway infrastructure. This analysis compares the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Lake Powell pool elevations
- Lake Mead pool elevations

Lake Powell

Critical high elevations at Lake Powell are listed in **Table TA 15-1** below. Reclamation minimizes controlled discharge over the spillway, as these discharges are not intended for frequent or extended operation. One way to reduce these controlled discharges is to maintain a vacant space requirement in the reservoir, which serves as a buffer of unused storage capacity to absorb large runoff inflows without causing controlled discharge.

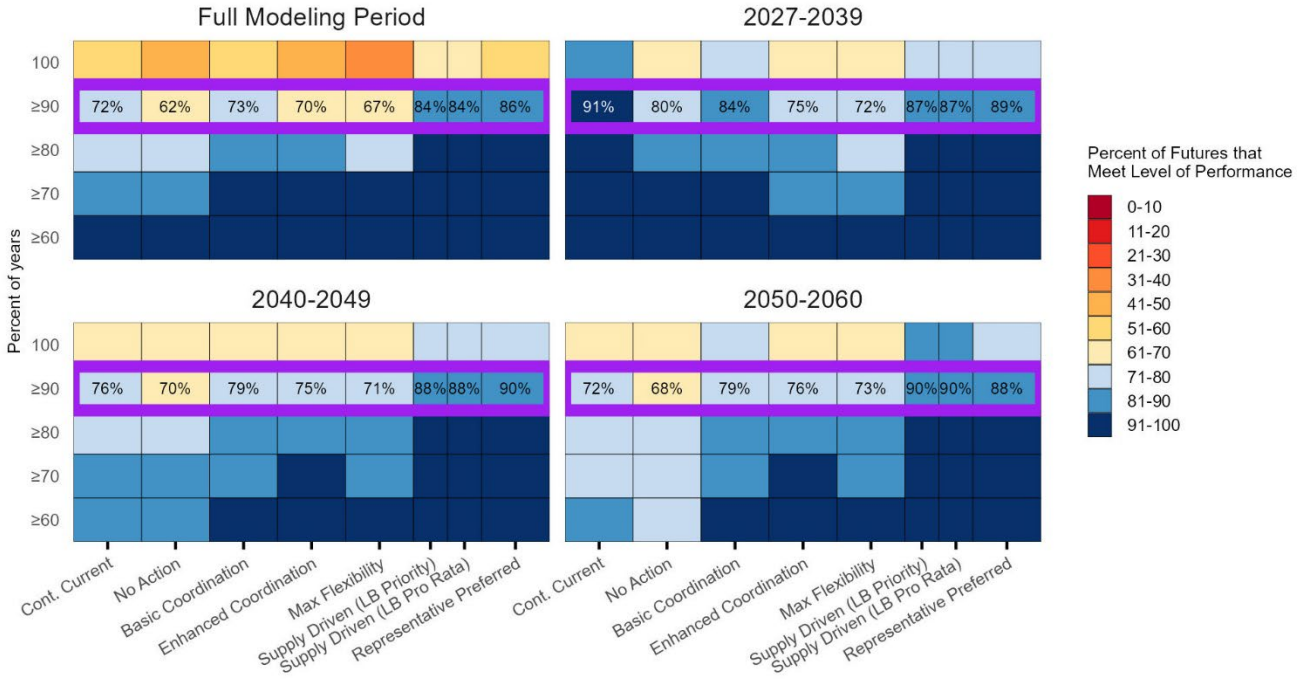
Table TA 15-1
Critical Elevations at Lake Powell

Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	3,700 feet	Glen Canyon Dam spillway
Vacant Space Requirement	3,684 feet	Target reservoir elevation on January 1. Allows for 1.9 maf of flood control storage up to the top of the spillway

Figure TA 15-22 below reports the percentage of futures in which Lake Powell elevation does not exceed 3,684 feet on January 1 in the percent of years specified by each row. Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains January 1 elevations below 3,684 feet in at least 90 percent of

years. Higher rows represent stricter performance requirements that are more difficult to achieve. Keeping Lake Powell below 3,684 feet ensures that sufficient reservoir volume is reserved to accommodate spring runoff.

Figure TA 15-22
Lake Powell Elevation 3,684 Feet: Robustness.
Percent of futures in which the January 1 Lake Powell elevation does not exceed 3,684 feet in the specified percent of years



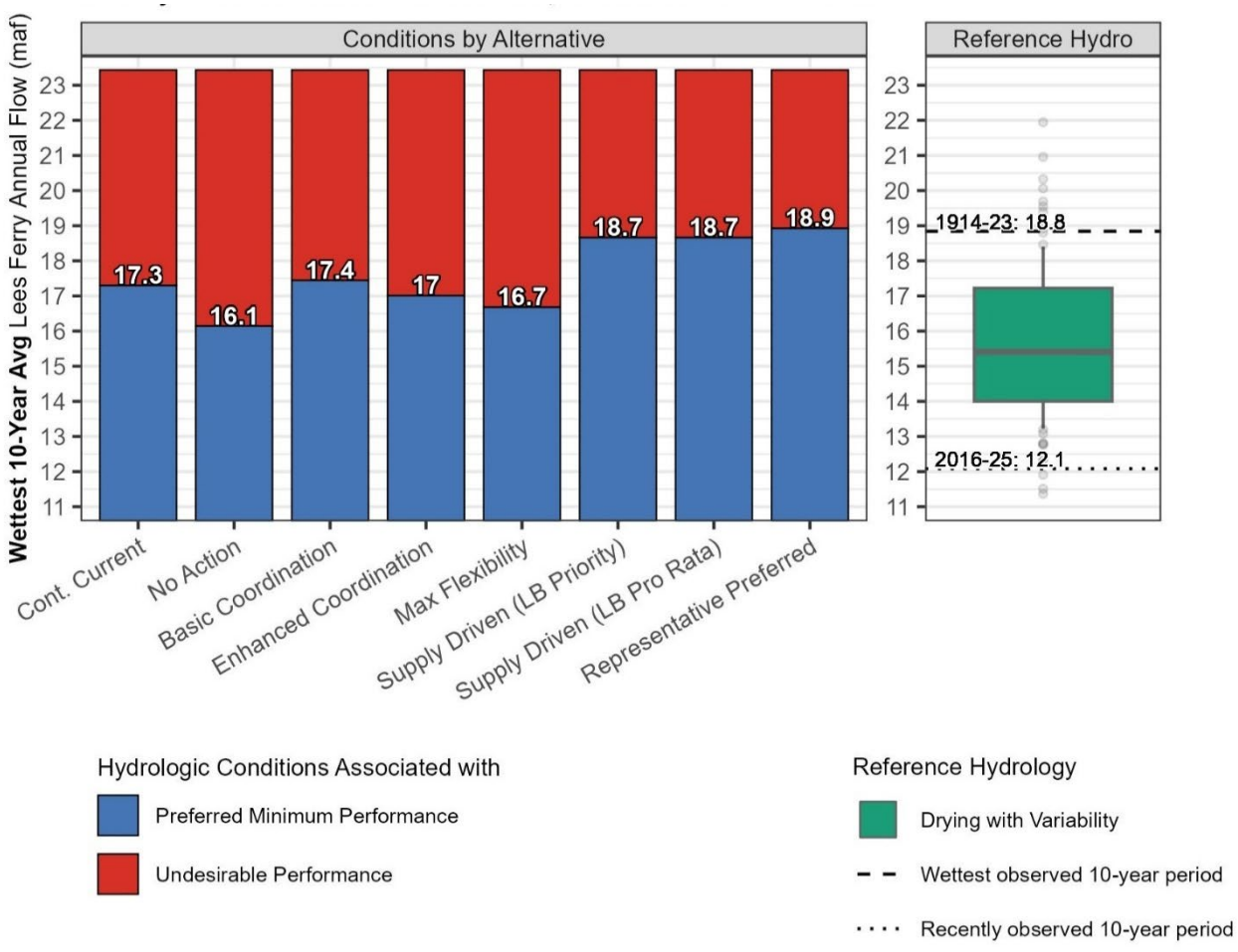
In the Full Modeling Period, the Representative Preferred Alternative is the most robust, meeting the preferred minimum level of performance in 86 percent of futures. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is the second most robust, meeting the preferred minimum level of performance in 84 percent of futures. The Basic Coordination, Maximum Operational Flexibility, Enhanced Coordination Alternatives, and the CCS Comparative Baseline perform similarly, meeting the preferred minimum performance in 67-73 percent of futures. The No Action Alternative has the worst performance at 62 percent of futures.

For the subperiod 2027-2039, the CCS Comparative Baseline was the most robust with 91 percent of futures meeting the preferred minimum performance. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives met the preferred minimum performance in 87 and 89 percent of futures, respectively. The No Action, Basic Coordination, Enhanced Coordination, and Maximum Operational Flexibility Alternatives experienced similarly high robustness, performing between 72-84 percent of years meeting the preferred minimum performance.

In the subperiods 2040-2049 and 2050-2060, the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives were the most robust, meeting the preferred minimum performance in 88-90 percent of futures. The No Action Alternative was the least robust meeting the preferred minimum performance in 68-70 percent of futures.

Figure TA 15-23 below looks at conditions that could cause the January 1 Lake Powell elevation to exceed 3,684 feet in 10 percent or more years. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-22**, which determined a future as successful when an alternative kept Lake Powell below this buffer elevation in at least 90 percent of years.

Figure TA 15-23
Lake Powell Preservation of Spring Runoff Space: Vulnerability.
January One Conditions that Could Cause Lake Powell Elevation Above 3,684 in 10 percent or More Years



For this vulnerability analysis, the wettest 10-year average of Lees Ferry Annual Flow was identified as a skillful predictor of undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow

from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison. The reference Drying with Variability median value is 15.4 maf.

The Supply Driven (both LB Priority and LB Pro Rata approaches) (18.7 maf) and Representative Preferred (18.9 maf) Alternatives are the least vulnerable; less than 10 percent of traces in the Drying with Variability Ensemble include conditions this wet. The CCS Comparative Baseline (17.3 maf) and Basic Coordination Alternative (17.4 maf) are vulnerable to about 25 percent of traces in the Drying with Variability Ensemble. The No Action (16.1 maf), Maximum Operational Flexibility (16.7 maf), and Enhanced Coordination (17.0 maf) Alternatives become vulnerable under less extreme wet conditions; between 25 and 50 percent of traces in the Drying with Variability Ensemble include conditions this wet. All alternatives are expected to satisfy the preferred minimum performance under the driest 50 percent of traces in the Drying with Variability Ensemble, which includes the recent 10-year average from 2016–2025 (12.1 maf).

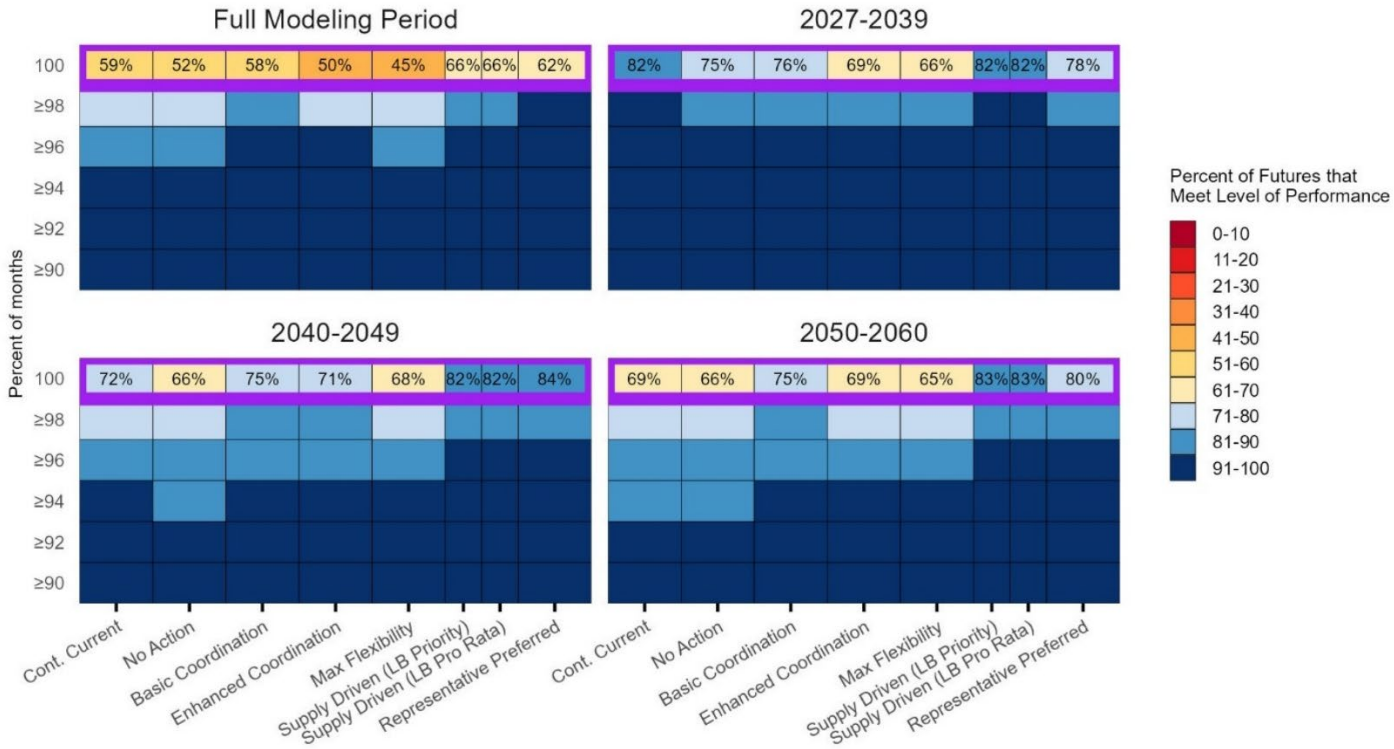
Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to January 1 Lake Powell elevation above 3,684 feet in more than 10 percent of years if the wettest 10-year average Lees Ferry annual flow is greater than 18.9 maf. This alternative is reasonably unlikely to be vulnerable in the next 10 years because the recently observed 10-year period is below 18.9 maf and fewer than 10 percent of traces in the Drying with Variability Ensemble include conditions this wet.

Figure TA 15-24 below depicts the ability of each alternative to maintain a Lake Powell pool elevation below 3,700 feet in the percentage of months specified by each row. Pool elevations below this threshold reduce the likelihood of large-magnitude spillway releases and provide an important buffer to protect dam infrastructure. Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains elevations below 3,700 feet in 100 percent of months.

Under the Full Modeling Period, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is the most robust, keeping Lake Powell below 3,700 feet in 66 percent of futures. The Representative Preferred Alternative was the second most successful at 62 percent of futures. The CCS Comparative Baseline and Basic Coordination Alternative are successful in 59 and 58 percent of futures, respectively. The No Action and Enhanced Coordination Alternatives are successful in 52 and 50 percent of futures. The Maximum Operational Flexibility Alternative was the least robust with 45 percent of futures meeting the preferred minimum performance.

In the three subperiods, the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives were the most robust, meeting the preferred minimum performance in 82 and 83 percent of futures, respectively. Basic Coordination Alternative performed consistently between 75-76 percent of futures. The CCS Comparative Baseline met the preferred minimum performance in 82 percent of futures during subperiod 2027–2039, with performance declining to 69 percent by subperiod 2050–2060. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives were consistently the least robust, meeting the preferred minimum performance between 65-75 percent of futures.

Figure TA 15-24
Lake Powell Elevation 3,700 Feet: Robustness.
Percent of futures in which Lake Powell elevation is below 3,700 feet in the specified percent of months

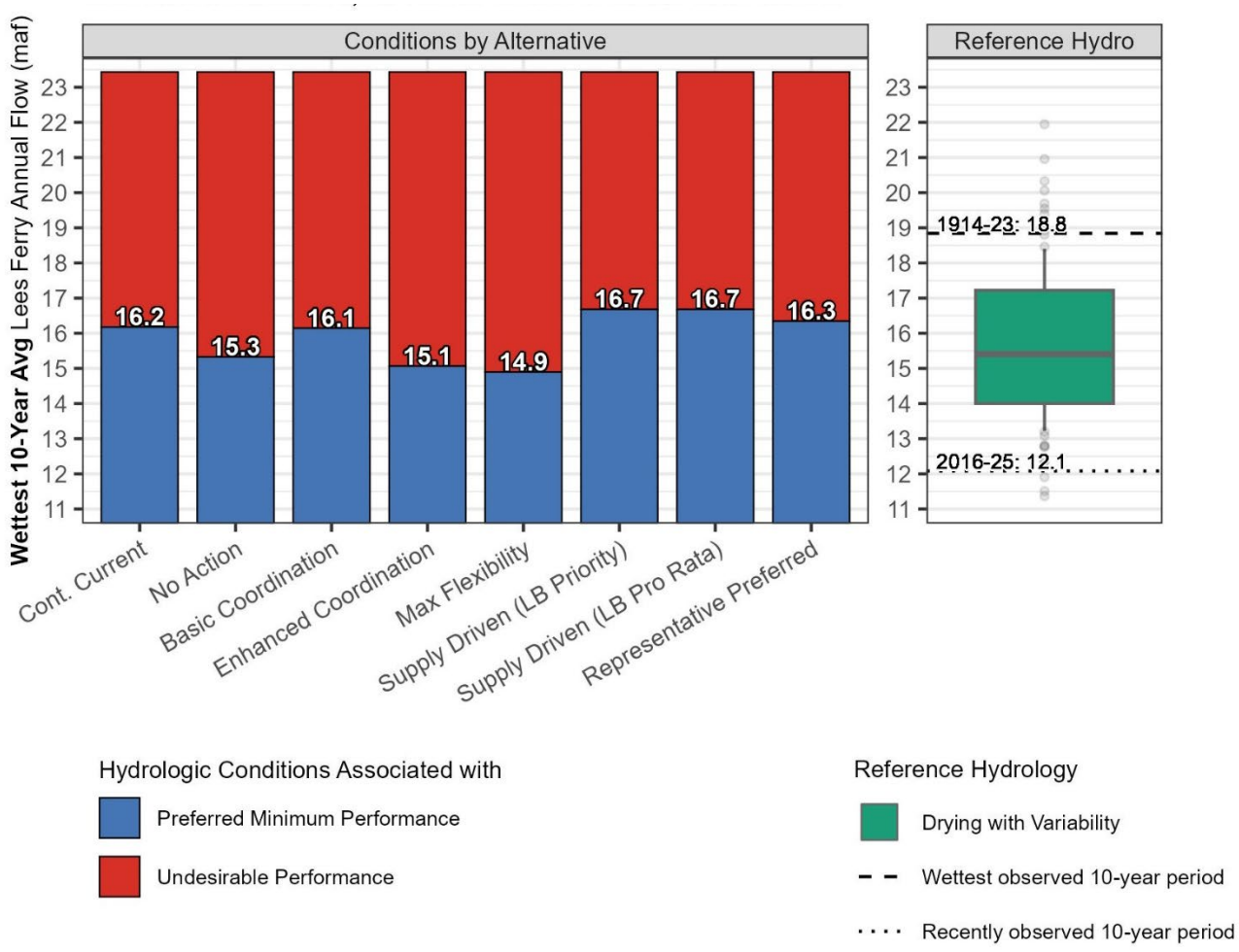


Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Maximum Operational Flexibility (66 percent) and Enhanced Coordination (69 percent) Alternatives are the least robust. All other alternatives and the CCS Comparative Baseline meet the preferred minimum performance level between 75 and 82 percent of futures, including the Representative Preferred Alternative (78 percent).

Figure TA 15-25 below shows what flow conditions are likely to cause the elevation of Lake Powell to exceed 3,700 feet in one or more months. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-24** above, which defined a future as successful when an alternative stayed below 3,700 feet in 100 percent of months. For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison. The reference Drying with Variability median value is 15.4 maf.

The No Action (15.3 maf), Enhanced Coordination (15.1 maf), and Maximum Operational Flexibility (14.9 maf) Alternatives show the most vulnerability being vulnerable in about 50 percent of traces in the Drying with Variability Ensemble. The CCS Comparative Baseline (16.2 maf), as well as Basic Coordination (16.1 maf) and Representative Preferred (16.3 maf) Alternatives are slightly less vulnerable. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is least vulnerable, reaching undesirable performance when the wettest 10-year average flow exceeds 16.7 maf. About 25 percent of traces in the Drying with Variability Ensemble exceed this value. The wettest observed 10-year average Lees Ferry annual flow in the historical record is approximately 18.8 maf; therefore, the vulnerability thresholds for all alternatives are below what has already occurred. However, the most recent 10-year average is 12.1 maf, which is significantly drier than the conditions expected to cause vulnerability.

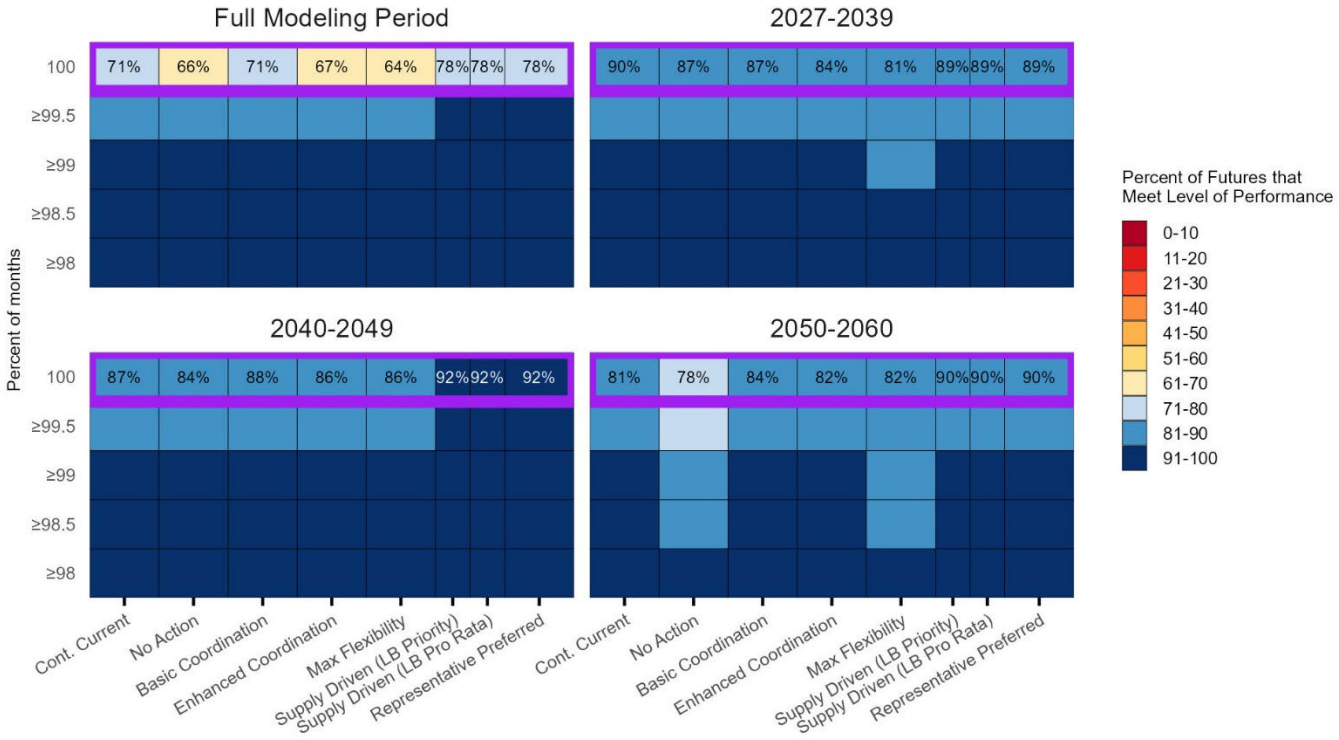
Figure TA 15-25
Lake Powell Preservation of Spring Runoff Space: Vulnerability.
Conditions that Could Cause Lake Powell Elevation Above 3,700 Feet or Greater in 10 percent or More Months



Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to at least one occurrence of Lake Powell elevation above 3,700 feet if the wettest 10-year average Lees Ferry annual flow is greater than 16.3 maf. This alternative may or may not be vulnerable in the next 10 years because different aspects of the Reference Hydrology panel conflict. Considering the Drying with Variability Ensemble, between 25-50 percent of traces are greater than 16.3 maf, suggesting this alternative may or may not be vulnerable. However, the recently observed 10-year period is below 16.3 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Figure TA 15-26 below shows the ability of each alternative to avoid Glen Canyon Dam spillway releases in the specified percent of months. Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative avoids spillway releases in 100 percent of months. Minimizing spillway releases maximizes water supply and power generation while reducing wear and tear to the spillway structure.

Figure TA 15-26
Glen Canyon Dam Spillway Releases: Robustness.
Percent of futures in which spillway releases are avoided in the specified percent of months



Under the Full Modeling Period, the Supply Driven (both LB Priority and LB Pro Rata approaches) and Representative Preferred Alternatives are most robust with 78 percent of futures meeting the preferred minimum performance, followed by Basic Coordination and CCS Comparative Baseline,

both at 71 percent, respectively. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives were the least robust in 64-67 percent of futures.

Under the three subperiods, all alternatives maintained a high level of robustness, with no alternative falling below 81 percent of futures meeting the preferred minimum performance. The only exception to this is in subperiod 2050-2060, where the No Action Alternative is less robust with 78 percent of futures meeting the preferred minimum performance.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. All alternatives and the CCS Comparative Baseline perform well, meeting the preferred minimum performance between 81 and 90 percent of futures. The Representative Preferred Alternative avoids using the Glen Canyon Dam spillway in 890 percent of futures.

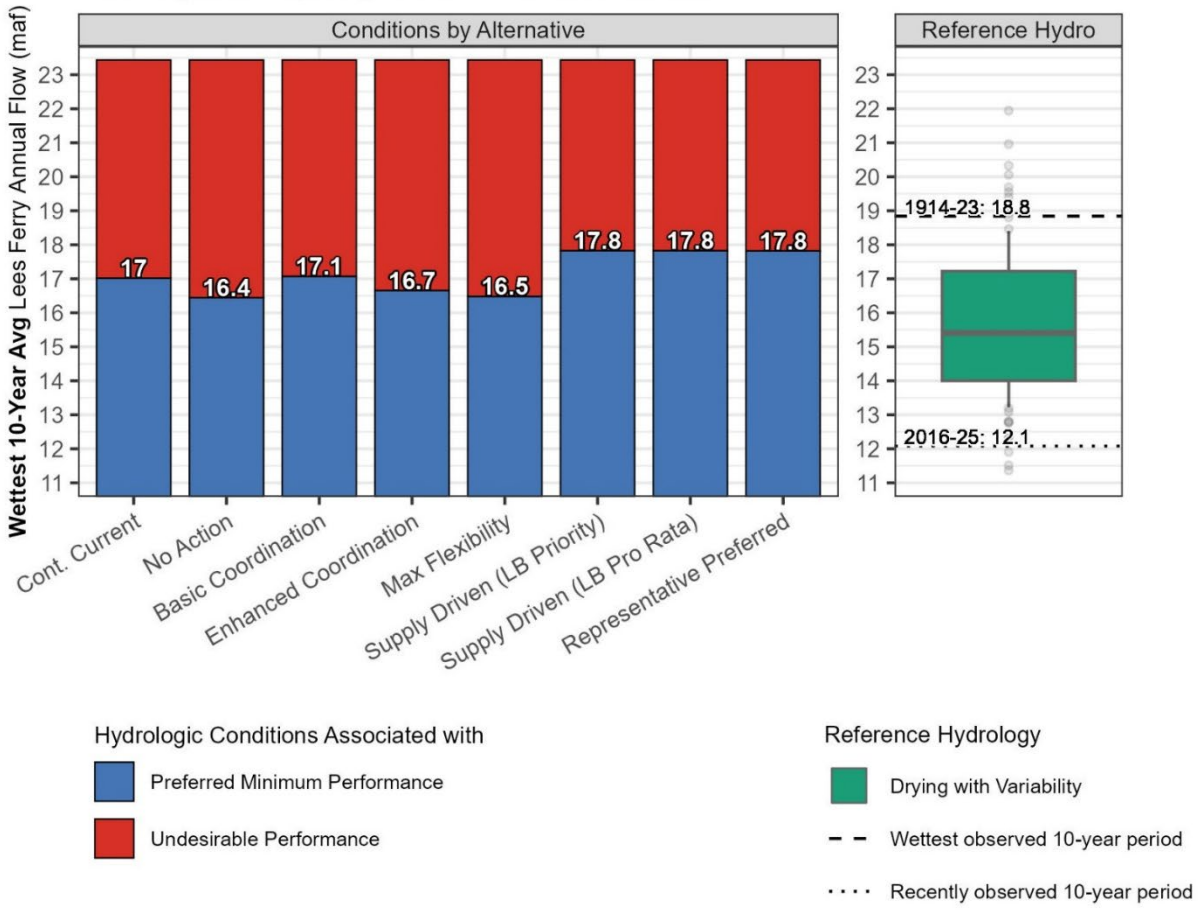
Figure TA 15-27 below shows what flow conditions are likely to cause Glen Canyon Dam spillway releases in one or more months. Spillway releases may result in reduced operational flexibility and increased flood control risk. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-26** which determined a future as successful when an alternative avoided spillway releases in 100 percent of months.

For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison. The reference Drying with Variability median value is 15.4 maf.

If the future includes a wettest 10-year average Lees Ferry annual flow of around 15.4 maf (i.e., the Drying with Variability median value), each alternative is suggested to avoid spillway releases in any month throughout the modeling period. The Supply Driven (both LB Priority and LB Pro Rata approaches at 17.8 maf) and Representative Preferred (17.8 maf) Alternatives require wetter hydrologic conditions before reaching undesirable performance and are less vulnerable compared to the other alternatives. The remaining alternatives reach undesirable performance at flows ranging from 16.4-17.1 maf, indicating greater vulnerability under comparatively lower flow conditions. All alternatives experience vulnerability to spillway releases under the wettest 10-year average in the historical record (18.8 maf).

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to one or more spillway releases if the wettest 10-year average Lees Ferry annual flow is greater than 17.8 maf. However, considering the Drying with Variability Ensemble, less than 25 percent of traces are greater than 17.8 maf, suggesting this alternative is reasonably unlikely to be vulnerable in the next 10 years. Further, the recently observed 10-year period is below 17.8 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Figure TA 15-27
Glen Canyon Dam Spillway Releases: Vulnerability.
Conditions that Could Cause Glen Canyon Dam Spillway Release in One or More Months



Lake Mead

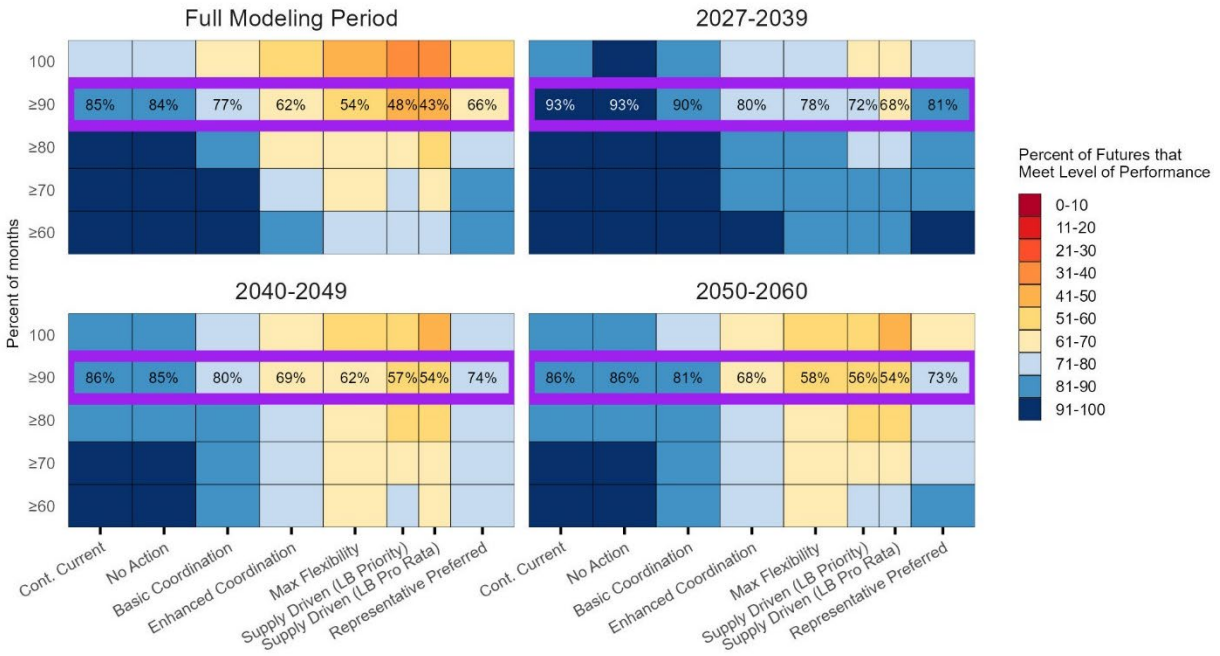
Critical high elevations at Lake Mead are listed in **Table TA 15-2** below. Reclamation minimizes uncontrolled discharge over the spillway as they are not intended for frequent or extended operation. One way to reduce these uncontrolled discharges is to maintain a vacant space requirement in the reservoir to absorb large runoff inflows without causing uncontrolled discharge.

Table TA 15-2
Critical Elevations at Lake Mead

Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	1,205.4 feet	Hoover Dam spillway crest
Maximum Operating Elevation	1,219.6 feet	Allows for 1.5 maf of flood control storage up to the top of the spillway
Maximum Spillway Discharge	1,226.9 feet	Spillway discharge at this elevation is 40,000 cfs, which triggers a "Imminent Life-Threatening Emergency" response

Figure TA 15-28 below reports the percentage of futures in which each alternative keeps Lake Mead below elevation 1,205.4 feet in the percent of months specified by each row. This elevation is the invert of the spillway drum gates for Hoover Dam, and operating above the spillway drum gates level increases the likelihood for mechanical failure. Four modeling periods are shown to capture the full modeling period, 2027-2039, 2040-2049, and 2050-2060. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative maintains elevations below 1,205.4 feet in at least 90 percent of months. 90 percent of the months was chosen as the preferred minimum performance level because it provides a reasonable amount of flexibility to infrequently go above 1,205.4 feet in very wet hydrology.

Figure TA 15-28
Hoover Dam Spillway Crest Avoidance: Robustness.
Percent of futures in which Lake Mead elevation does not exceed 1,205.4 feet in the specified percent of months



In the Full Modeling Period, the CCS Comparative Baseline and the No Action Alternative are most robust at staying below elevation 1,205.4 feet in 85 and 84 percent of futures, respectively. The Basic

Coordination (77 percent), the Representative Preferred (66 percent), and Enhanced Coordination (62 percent) Alternatives futures follow. The Maximum Operational Flexibility (54 percent) and the Supply Driven (both LB Priority at 48 percent and LB Pro Rata at 43 percent) Alternatives are the least robust.

Across the three subperiods, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is the least robust, while the CCS Comparative Baseline and No Action Alternative were the most robust with 85-93 percent of futures meeting the preferred minimum.

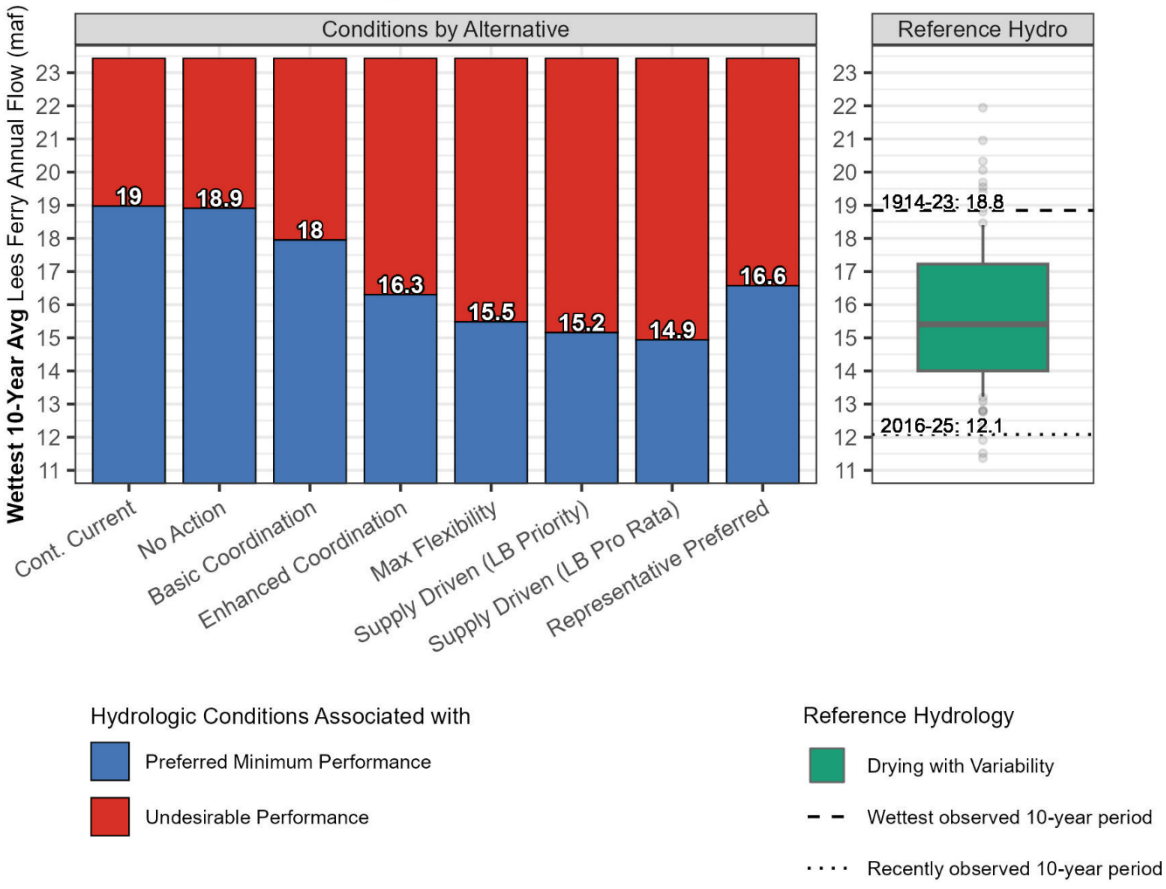
Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The CCS Comparative Baseline and No Action Alternative are the most robust (both 93 percent), followed closely by the Basic Coordination Alternative (90 percent). The Representative Preferred (81 percent), Enhanced Coordination (80 percent), and Maximum Operational Flexibility (78 percent) Alternatives are similar. The Supply Driven (LB Priority approach) Alternative (72 percent) and Supply Driven (LB Pro Rata approach) Alternative (68 percent) are the least robust.

Figure TA 15-29 below shows what flow conditions are likely to cause the elevation of Lake Mead to exceed 1,205.4 feet in at least 10 percent of months. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-28** above, which defined a future as successful when an alternative stayed below 1,205.4 feet in at least 90 percent of months.

For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

If the future includes a wettest 10-year average Lees Ferry annual flow of around 15.4 maf (i.e., the Drying with Variability median value), modeling results indicate undesirable performance for the Supply Driven (both LB Priority [15.2 maf] and LB Pro Rata [14.9 maf] approaches) Alternative. This alternative, along with the Maximum Operational Flexibility (15.5 maf) Alternative, reach undesirable performance at comparatively lower flow thresholds, indicating higher vulnerability. The Representative Preferred (16.6 maf) and Enhanced Coordination (16.3 maf) display less vulnerability by performing above the median 10-year average Lees Ferry annual flow of 15.4 maf. The Basic Coordination (18 maf) and No Action (18.9 maf) Alternatives, as well as the CCS Comparative Baseline (19 maf), require wetter hydrologic conditions to reach undesirable performance and are therefore the least vulnerable alternatives. Under the No Action Alternative and CCS Comparative Baseline, Lake Mead elevations above 1,205.4 feet in more than 10 percent of months appear unlikely under most Drying with Variability traces, as the vulnerability thresholds of 18.9 maf and 19 maf, respectively, exceed the 90 percentile of the Drying with Variability Ensemble. From 1914 to 1923, the wettest 10-year average was 18.8 maf. All alternatives, with exception of the CCS Comparative Baseline and No Action Alternative, are vulnerable to conditions that have already occurred.

Figure TA 15-29
Hoover Dam Spillway Crest Avoidance: Vulnerability.
Conditions that could cause Lake Mead elevation above 1,205.4 feet in 10 percent or more months

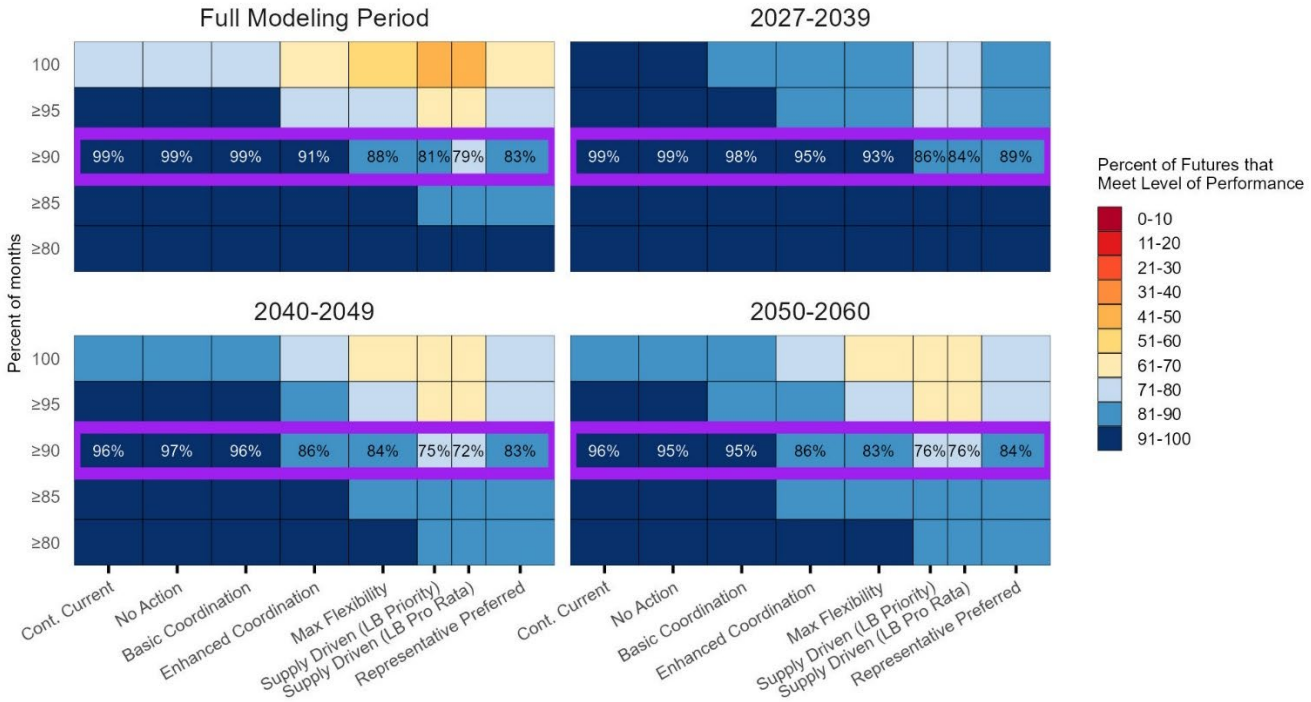


Modeling indicates that the Representative Preferred Alternative would likely be vulnerable if the wettest 10-year average annual flow at Lees Ferry exceeds 16.6 maf, resulting in Lake Mead elevations above 1,205.4 feet in at least 10 percent of months. However, considering the Drying with Variability Ensemble, about 25 percent of traces are greater than 16.6 maf, suggesting this alternative is reasonably unlikely to be vulnerable in the next 10 years. Further, the recently observed 10-year period is below 16.6 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Figure TA 15-30 below depicts the ability of each alternative to maintain a Lake Mead pool elevation below 1,219.6 feet in the specified percent of months, which is an important flood buffer elevation for protecting dam infrastructure. The model evaluates multiple future simulation periods, including three subperiods: 2027–2039, 2040–2049, and 2050–2060. Results shown for the Full Modeling Period reflect performance across the complete modeled timeframe, rather than any individual subperiod. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative is below 1,219.6 feet in at least 90

percent of months. The greater than or equal to 90 percent row was chosen because it provides a reasonable amount of flexibility to go above 1,219.6 feet occasionally in very wet hydrology.

Figure TA 15-30
Avoidance of Lake Mead Maximum Operating Elevation: Robustness. Percent of futures in which Lake Mead elevation does not exceed 1,219.6 feet in the percent of months specified in each row



Over the Full Modeling Period, the CCS Comparative Baseline, as well as Basic Coordination and No Action Alternatives are successful at keeping Lake Mead below 1,219.6 feet in 99 percent of futures. The Maximum Operational Flexibility and Representative Preferred Alternatives meets this threshold in 88 percent and 83 percent of futures, respectively. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is least robust, with the preferred minimum performance met in 81 and 79 percent of futures, respectively.

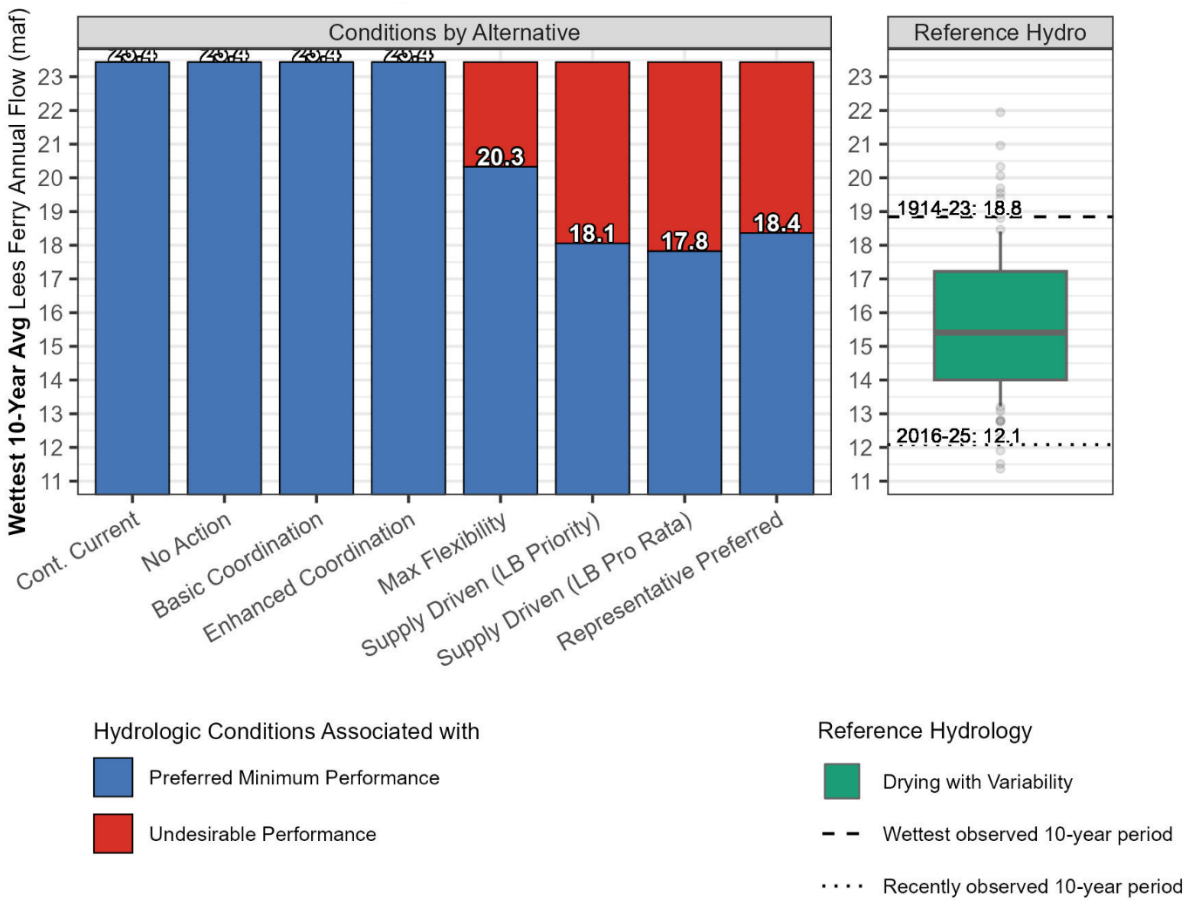
The subperiod 2027-2039 experiences high robustness across all alternatives, with the Supply Driven (both LB Priority [86 percent] and LB Pro Rata [84 percent]) Alternative being least robust. The subperiods 2040-2049 and 2050-2060 have slightly reduced robustness in respect to the subperiod 2027-2039, as the Enhanced Coordination (86 percent), Maximum Operational Flexibility (83-84 percent), Representative Preferred (83-84 percent), and Supply Driven (both LB Priority and LB Pro Rata approaches) (72-76 percent) Alternatives fall slightly.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. All alternatives perform well, meeting the preferred minimum performance between 84 percent (Supply Driven [LB Pro Rata approach]) and 99 percent (No Action) of futures.

The Representative Preferred Alternative meets the preferred minimum performance level in 89 percent of futures.

Figure TA 15-31 below shows what flow conditions are likely to cause the elevation of Lake Mead to exceed 1,219.6 feet in more than 10 percent of months, as elevations above this level may reduce available flood control capacity and operational flexibility. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-30** above, which defined a future as successful when an alternative stayed below 1,219.6 feet in at least 90 percent of months.

Figure TA 15-31
Avoidance of Lake Mead Maximum Operating Elevation: Vulnerability. Conditions that could cause Lake Mead elevation to exceed 1,219.6 feet in 10 percent or more months



For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The CCS Comparative Baseline (23.4 maf), as well as No Action (23.4 maf), Basic Coordination (23.4 maf), and Enhanced Coordination (23.4 maf) Alternatives require wetter hydrologic conditions to reach undesirable performance and are therefore less vulnerable. These alternatives demonstrated no vulnerability for the full range of reference hydrology Drying with Variability traces, indicating a low likelihood that Lake Mead elevation would rise above 1,219.6 feet in more than 10 percent of months. The wettest 10-year average Lees Ferry annual flows for the Maximum Operational Flexibility (20.3 maf), Representative Preferred (18.4 maf), and Supply Driven (both LB Priority [18.1 maf] and LB Pro Rata [17.8 maf] approaches) Alternatives are comparatively lower; though, above the Drying with Variability median wettest 10-year average Lees Ferry annual flow of 15.4 maf.

Modeling indicates that the Representative Preferred Alternative would likely be vulnerable if the wettest 10-year average annual flow at Lees Ferry exceeds 18.4 maf, resulting in Lake Mead elevations above 1,219.6 feet in at least 10 percent of months. However, considering the Drying with Variability Ensemble, only about 10 percent of traces are greater 18.4 maf, suggesting this alternative is reasonably unlikely to be vulnerable in the next 10 years. The recently observed 10-year period is well below 18.4 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Figure TA 15-32 below depicts the ability of each alternative to maintain a Lake Mead pool elevation below 1,226.9 feet in the specified percent of months. The analysis evaluates multiple future simulation periods, including three modeled subperiods: 2027–2039, 2040–2049, and 2050–2060. In addition to these subperiods, the Full Modeling Period refers to the entire future simulation horizon evaluated for each modeled future, encompassing all years in the analysis. The preferred minimum performance is shown in the purple highlighted row, which represents the percentage of futures that an alternative is below 1,226.9 feet in 100 percent of months. At this elevation, spillway releases exceed 40,000 cfs, which is considered a life-threatening emergency downstream.

Under the Full Modeling Period, the Supply Driven (both LB Priority [73 percent] and LB Pro Rata [70 percent] approaches) Alternative is the least robust. The Maximum Operational Flexibility (82 percent) performs similarly to Enhanced Coordination (83 percent) and Representative Preferred (78 percent) Alternatives. The No Action (92 percent) and Basic Coordination (91 percent) Alternatives, as well as CCS Comparative Baseline (92 percent), are the most robust with Lake Mead remaining below the critical level of 1,226.9 feet in 100 percent of futures. If the requirement relaxes to staying below 1,226.9 feet at Lake Mead in 98 percent of futures, all alternatives increase in robustness. For the subperiods, alternatives range between 84 to 98 percent of futures meeting the preferred minimum performance.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. All alternatives perform well, meeting the preferred minimum performance between 88 and 98 percent of futures. The Representative Preferred Alternative meets the preferred minimum performance in 93 percent of futures.

Figure TA 15-32
Avoidance of Lake Mead Maximum Spillway Discharge: Robustness.
Percent of futures in which Lake Mead elevation does not exceed 1,226.9 feet in the specified percent of months



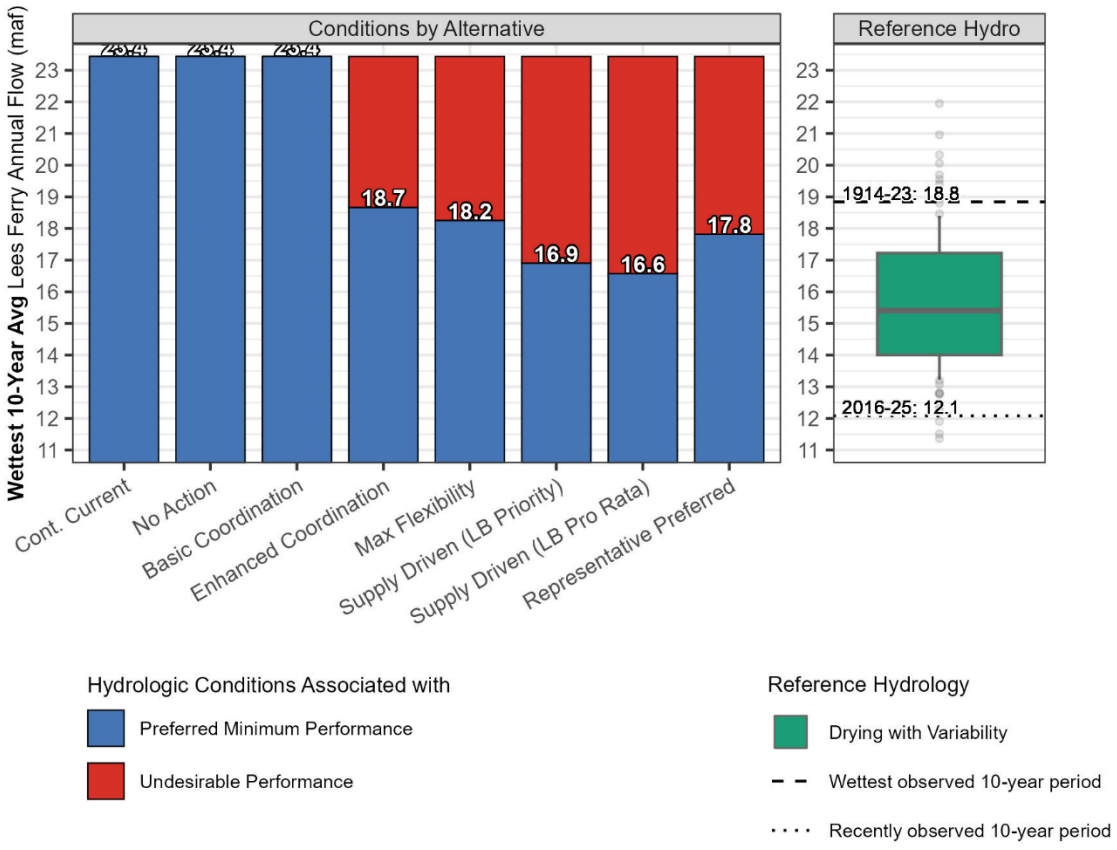
Representative Preferred **Figure TA 15-33** below shows what flow conditions are likely to cause the elevation of Lake Mead to exceed 1,226.9 feet in any month. At this elevation, release flows exceed 40,000 cfs, which is considered an emergency downstream. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-32**, which specified that a future was successful if Lake Mead stayed below 1,226.9 feet in 100 percent of months.

For this vulnerability analysis, the wettest 10-year average Lees Ferry annual flow was determined to be skillful at predicting undesirable performance. The vulnerability threshold for each alternative is described and compared to the Drying with Variability Ensemble using this streamflow summary statistic. The wettest observed 10-year average flow from 1914-1923 (18.8 maf) and the average flow from 2016-2025 (12.1 maf) are also provided as dashed and dotted lines, respectively, for comparison.

The CCS Comparative Baseline (23.4 maf), as well as No Action (23.4 maf) and Basic Coordination (23.4 maf) Alternatives require wetter hydrologic conditions to reach undesirable performance and are therefore less vulnerable. Zero traces in the Drying with Variability Ensemble exhibit these conditions, indicating a low likelihood that Lake Mead elevation would rise above 1,226.9 feet in any month. The wettest 10-year average Lees Ferry annual flows for the Enhanced Coordination (18.7 maf), Representative Preferred (17.8 maf), Maximum Operational Flexibility (18.2 maf), and Supply Driven (both LB Priority [16.9 maf] and LB Pro Rata [16.6 maf] approaches) Alternatives are

comparatively lower; though, above the Drying with Variability median wettest 10-year average Lees Ferry annual flow of 15.4 maf.

Figure TA 15-33
Avoidance of Lake Mead Maximum Spillway Discharge: Vulnerability. Conditions that could cause Lake Mead elevation to exceed 1,226.9 feet in 1 or more months



Modeling indicates that the Representative Preferred Alternative would likely be vulnerable to one or more occurrences of Lake Mead elevation above 1,226.9 feet if the wettest 10-year average Lees Ferry annual flow is greater than 17.8 maf. However, considering the Drying with Variability Ensemble, less than 25 percent of traces are greater than 17.8 maf, suggesting this alternative is reasonably unlikely to be vulnerable in the next 10 years. The recently observed 10-year period is well below 17.8 maf, suggesting that this alternative is unlikely to be vulnerable if the next 10 years are similar to or drier than the most recent 10 years.

Summary of Issue 4 Impacts

From a spillway use perspective, keeping the reservoir water level below the spillway crest minimizes spillway drum gate use and spillway use, preserves the water supply, maintains flood storage capacity, and reduces wear and tear on spillway infrastructure. Maintaining lower reservoir levels allows inflow to be routed through controlled outlets and respond to spring runoff. The alternatives generally perform similarly under wet hydrologic flow conditions, apart from the Supply Driven

Alternative (both LB Priority and LB Pro Rata approaches) generally performing best for Lake Powell and the No Action Alternative and the CCS Comparative Baseline performing best for Lake Mead.

High elevation reservoir infrastructure and critical flood storage buffers for Glen Canyon Dam and Lake Powell are better protected under the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative during wetter hydrological conditions. Conversely, at Hoover Dam and Lake Mead, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative has the least preferred performance in terms of keeping Lake Mead below critical high elevations. For Lake Mead, the duration spent above these high-water thresholds is minimized under the No Action and Basic Coordination Alternatives and the CCS Comparative Baseline. Under the Basic Coordination Alternative, both Glen Canyon Dam and Hoover Dam achieve preferred minimum performance and high-water thresholds are minimized. The Enhanced Coordination and Maximum Operational Flexibility Alternatives provide the second and third most preferred performance when considering Glen Canyon Dam and Hoover Dam collectively. The performance of the Representative Preferred Alternative varied, generally ranking from mid- to upper-performing at Glen Canyon Dam and roughly the middle-performing alternative at Hoover Dam.

TA 15.2.7 Issue 5: How would changes in energy generation impact electricity rates and the market value of electricity?

Glen Canyon Dam

Argonne National Laboratories and WAPA's report, "Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project" (Yu et al. 2025), assessed the relative impacts of various Glen Canyon Dam hydrological scenarios on the CRSP's Firm Electric Service rates. This analysis utilized an advanced simulation tool to estimate future generation production along with a stepwise rate adjustment framework. This framework is consistent with CRSP's obligation to remain financially self-sustaining and deliver cost-based power services (DOE 2025) and was used to evaluate the rate implications of simulated Glen Canyon Dam-only generation outcomes. It is important to note that CRSP's Firm Electric Service rates encompass hydropower generation resources beyond Glen Canyon Dam; therefore, the identified rate impacts are theoretical, representing uncertainty associated with future Glen Canyon Dam hydrological conditions. The report found that the Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently yielded more favorable hydropower generation outcomes, associated with higher electricity production. These alternatives also indicated fewer rate adjustments, smaller average increases per adjustment, and substantially lower maximum rate increases when an increase was identified. Specifically, under wet or average hydrologic conditions, these alternatives led to results similar to or slightly better than other alternatives. Under dry hydrologic conditions, they resulted in substantially smaller rate increases and less frequent rate adjustments. Overall, Enhanced Coordination and Maximum Operational Flexibility are identified as entailing less adverse economic impact on U.S. electricity consumers and providing greater protection against extreme adverse outcomes compared to the other five alternatives. The modeling framework and key methodological choices supporting these findings, as documented in Yu et al. (2025), included comprehensive data on CRSP's plant characteristics, hydrological conditions, Argus forward prices, and CRSP's power purchase and sales transactions. Another important point to note is that the rate adjustment

framework used in the study is a simplified version of actual rate-changing processes, as it is based solely on assumed revenue requirements and simulated electricity production. Consequently, it provides a directional analysis for comparing policy scenarios rather than forecasting actual consumer rates, requiring careful contextualization to avoid misinterpretation. Extreme hydrological conditions, potentially leading to very low or even zero simulated electricity production, can result in a non-trivial subset of degenerate results, projecting unrealistic rate increases or decreases. These extreme events, particularly zero electricity production from Glen Canyon Dam, are unprecedented and fall outside the scope of the current analysis framework, as they cannot be resolved through standard rate adjustments.

Figure TA 15-34 shows the estimated annual market value of hydropower generation by combining modeled annual energy production with an illustrative wholesale electricity price. A fixed 2028 fiscal year value per MWhs was developed using Argonne National Laboratory available data and multiplies it by the annual generation from WAPA's CRiSPPy model. Results were then applied uniformly across all alternatives and five potential flow categories (Wet Flow Category, Moderately Wet Flow Category, Average Flow Category, Dry Flow Category, and Critically Dry Flow Category). The box plots show variability in annual generation value (in millions of dollars) across futures within each flow category, highlighting how both hydrologic conditions and alternative operations influence potential energy value.

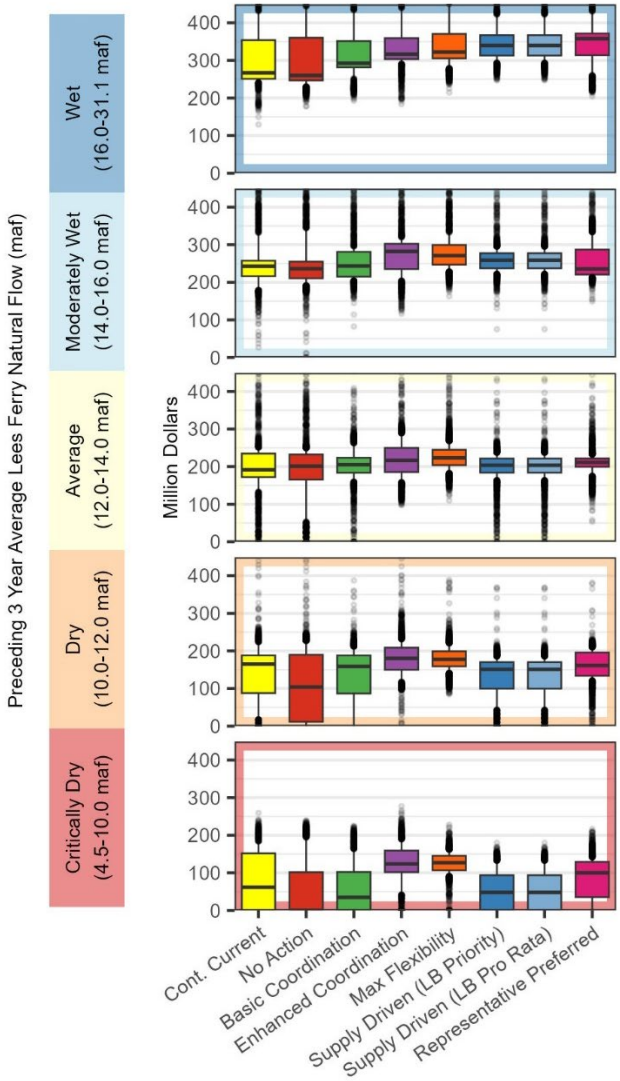
In the Wet Flow Category, the Representative Preferred Alternative resulted in the highest overall annual generation with a median value of $358 million. The Supply Driven (both LB Pro Rata and LB Priority approaches) Alternative experienced high median value of $340 million annually. The CCS Comparative Baseline ($267 million) and No Action Alternative ($260 million) had the lowest median values.

Within the Moderately Wet Flow Category, all alternatives retain similar metrics with relatively narrower interquartile ranges, indicating strong and consistent performance. However, Enhanced Coordination and Maximum Operational Flexibility experienced slightly higher median values than the others, with median values of $282 million and $271 million, respectively.

The Average Flow Category had similar performance across all alternatives and with relatively narrow interquartile ranges. The CCS Comparative Baseline had the lowest median value of $190 million, while the Maximum Operational Flexibility Alternative experienced the highest median value of $223 million.

Under the Dry Flow Category, Enhanced Coordination and Maximum Operation Flexibility had higher median values of $180 and $178 million, respectively. The No Action Alternative had the lowest value among the other alternatives, at $104 million. Both the CCS Comparative Baseline and No Action Alternative showed the widest interquartile ranges, with 25th percentiles of $12 million for the No Action Alternative and $88 million for the CCS Comparative Baseline. These larger interquartile ranges suggest greater variability in annual generation value compared to the other alternatives.

Figure TA 15-34
Annual Market Value of Glen Canyon Dam Generation: Box Plots



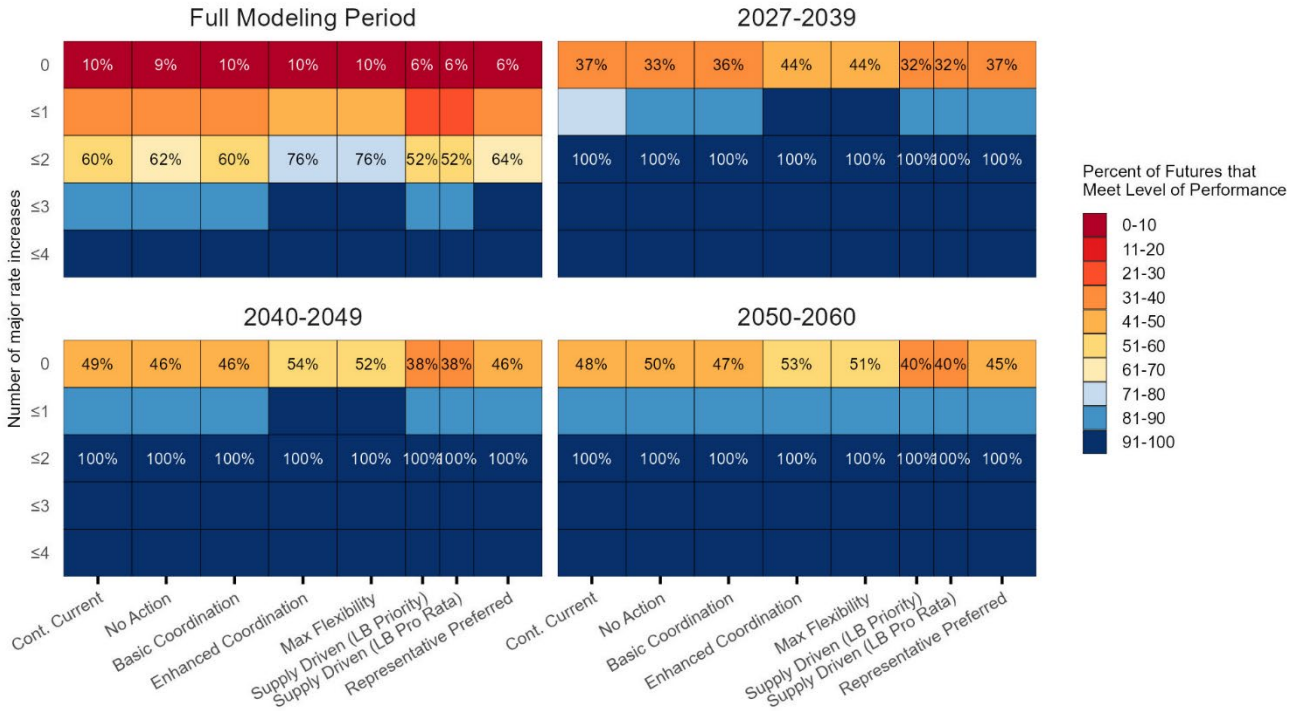
The Critically Dry Flow Category resulted in the lowest overall annual values for all alternatives. The Enhanced Coordination and Maximum Operational Flexibility Alternatives showed the narrowest interquartile ranges and highest median annual value, with median values of $124 million and $127 million. The Representative Preferred Alternative resulted in a median value of $100 million annually but with much larger interquartile ranges than the Enhanced Coordination and Maximum Operation Flexibility Alternatives. All other alternatives and CCS Comparative Baseline exhibited similarly larger interquartile ranges, but with at least 25 percent of years having values reach $0.

The Representative Preferred Alternative maintained relatively high median annual values under dry ($161 million) and critically dry ($100 million) flow conditions, outperforming the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

Figure TA 15-35 below shows the number of futures where CRSP customers could potentially see major rate increases under each alternative across the modeled futures at Glen Canyon Dam. The rows of the heat map represent the number of times in which there is major rate increases at or below a given threshold.

Figure TA 15-35 shows results for the Full Modeling Period and three subperiods: 2027-2039, 2040-2049, and 2050-2060. Consistent with WAPA's rate-setting procedures, cost-based rates are reviewed and adjusted on a five-year cycle. Therefore, the maximum number of rate changes that can occur in any of the three subperiods is 2.

Figure TA 15-35
Glen Canyon Dam CRSP Major Rate Increases: Robustness.
Percent of futures with the specified number of major rate increases



Note: Robustness modeling for the anticipated number of major rate increases was performed only for Glen Canyon Dam, based on historical rate information provided by WAPA. Each subperiod reflects the average of two rate evaluations, consistent with WAPA's rate-setting practices, which generally involve reviewing and adjusting rates on a five-year cycle but may occur more frequently in response to changing operational or hydrologic conditions.

For the Full Modeling Period, the Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust with respect to limiting major rate increases to two or fewer times, doing so in 76 percent of futures. By comparison, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative is the least robust. Only 52 percent of futures under these alternatives remain at or below two major rate increases, and a larger share of futures exceed this threshold, indicating greater exposure to repeated or sustained rate adjustments. The CCS Comparison Baseline, as well as the No Action, Representative Preferred, and Basic Coordination Alternatives,

perform intermediately, with 60 to 64 percent of futures remaining at or below two major rate increases, and declining robustness for all alternatives at more stringent performance thresholds.

Based on the planned length of this decision, it is important to compare robustness in the 2027-2039 modeling period. The Enhanced Coordination and Maximum Operational Flexibility Alternatives are the most robust at having 0 rate increases, doing so in 44 percent of modeled futures. The Representative Preferred Alternative and CCS Comparative Baseline are the next most robust, both having 0 rate increases in 37 percent of futures. All alternatives have 1 or less rate increases in 81 percent or more of futures. As noted above, WAPA's rates are reviewed and adjusted on a five-year cycle. Since the subperiods range from 9 – 12 years, it is not possible to trigger 3 or more rate increases in a subperiod, so all alternatives have a score of 100 percent in the rows for 2, 3, and 4 rate increases.

Hoover Dam

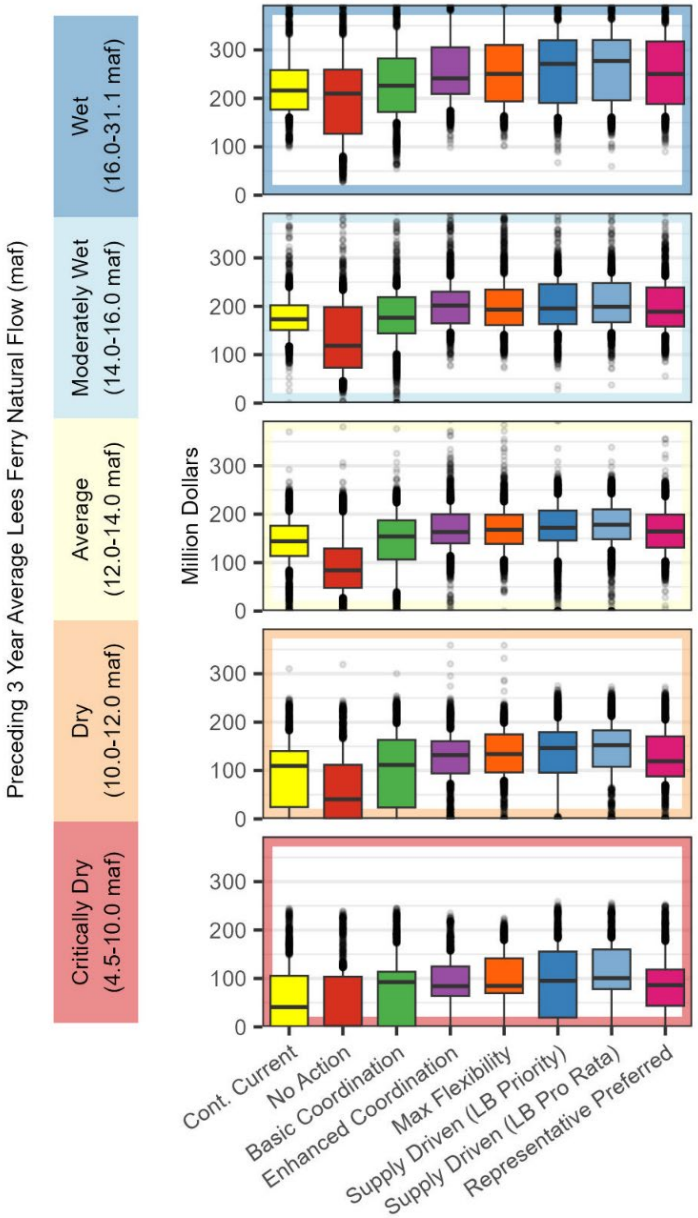
Hoover Dam provides federally marketed hydropower to Arizona, California, and Nevada through the BCP, managed by WAPA. Funding for the project's operation, maintenance, and capital costs is entirely self-supported by these hydropower sales to contracted entities, requiring no taxpayer funding. Historically, cost-based rates kept Hoover power lower than regional wholesale market alternatives. Under this framework, customers pay a fixed annual base charge to cover these costs, allocated by contract share rather than actual generation. However, as declining water levels reduce generation output, the unit cost of the remaining power rises. This creates a financial swing: when generation drops sufficiently, Hoover Dam's unit cost surpasses market rates, making power uneconomical and potentially forcing contracted entities to abandon their long-term contracts.

Figure TA 15-36 below shows the annual market value of hydropower at Hoover Powerplant. The economic analysis is based on a dollar-per-MWhs value provided by the Lower Basin Dams Office using WY 2027 data. The dollar-per-MWhs rate was then multiplied by the modeled energy generation from CRSS to compute market value. The market value depends on water surface elevation, with values being greater if elevation is above 1,035 feet and lower if below 1,035 feet. To show how market value can change due to different hydrology, results are grouped into five flow categories: (Wet Flow Category, Moderately Wet Flow Category, Average Flow Category, Dry Flow Category, and Critically Dry Flow Category).

Under the Wet Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative result in the highest median market values of approximately $271-277 million annually. All other alternatives had a median market value that exceeded $200 million. The No Action Alternative had a value of $127 million or less in 25 percent of years, much lower than all other alternatives.

Within the Moderately Wet Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative experienced the highest 75th percentiles ($246-248 million) and 25th percentiles ($163-167 million). Similar to the Wet Flow Category, the No Action Alternative had the lowest median market value and the largest interquartile range, with a 25th percentile of $73 million and 75th percentile of $198 million.

Figure TA 15-36
Annual Market Value of Hoover Dam Generation: Box Plots



Under the Average Flow Category, most alternatives see a median market value decline to below $200 million. The Enhanced Coordination ($163 million), Maximum Operational Flexibility ($168 million), Supply Driven (both LB Priority and LB Pro Rata approaches) ($172 million and $178 million, respectively), and Representative Preferred ($165 million) Alternatives generally maintain higher medians and moderate interquartile ranges, while the No Action ($84 million) and Basic Coordination ($154 million) Alternatives tend to show lower medians and greater variability.

Dry and Critically Dry Flow Categories resulted in the lowest overall annual values. Maximum Operational Flexibility ($142-$175 million), Basic Coordination ($93-$112 million), Representative

Preferred ($86-119 million), and Supply Driven (LB Pro Rata approach) ($160-$183 million) Alternatives showed the highest median annual values. Basic Coordination Alternative resulted in a higher median value but with much larger interquartile ranges than the other alternatives. The CCS Comparative Baseline, No Action and Basic Coordination Alternatives all fall to $0 in 25 percent or more years.

Modeling indicates that the Representative Preferred Alternative maintained a median value of $119 million annually under the Dry Flow Category and $86 million under the Critically Dry Flow Category. In the Critically Dry Flow Category, the 25th percentile is $44 million.

Davis and Parker Dam

The PDP is a federally operated system combining the Parker and Davis Dam hydroelectric facilities and transmission infrastructure on the Colorado River. Reclamation operates and maintains the dams and powerplants, while WAPA markets and transmits the generated electricity to customers under long term contracts.

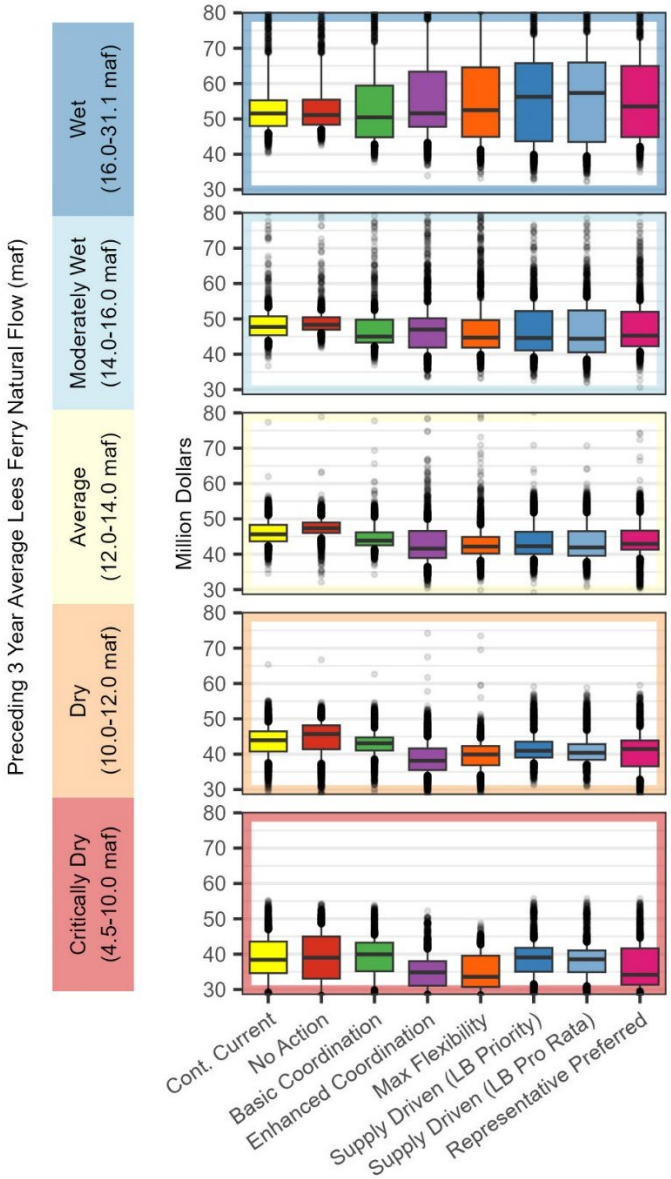
WAPA sets rates using a cost-recovery framework designed to recover annual project costs including operations, maintenance, replacements, and federal investment repayment. WAPA currently markets the project as a firm, fixed monthly delivery obligation, purchasing supplemental wholesale power to meet this commitment. Declining generation from the powerplants has increased the need for supplemental power, driving significant rate increases due to market price volatility. Starting in October 2028, a new marketing plan will align WAPA's delivery obligations with hydropower availability. This change will potentially create a financial swing. If generation drops sufficiently, PDP rates could surpass market rates, making the power uneconomical and potentially forcing contracted entities to abandon their long-term contracts.

Figure TA 15-37 below shows the annual market value of hydropower at Davis Dam based on CRSS modeling of generation and an assumed dollar-per-MWhs rate to determine the financial value (in millions of dollars). The results are grouped by preceding 3-year average Lees Ferry natural flow to show how fiscal value is influenced by hydrology for each alternative. Differences in fiscal value are driven by differences in releases across the alternatives (see **Figure TA 3-26** in **TA 3**, Hydrologic Resources for calendar year releases from Davis Dam).

Under the Wet Flow Category, all action alternatives exhibit relatively large interquartile ranges, indicating that hydropower value at Davis Dam is sensitive to operational differences during favorable hydrologic conditions. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative experienced the highest median value of $56-57 million annually, followed by Representative Preferred Alternative at $54 million. The Basic Coordination Alternative produced the lowest median market value, at $50 million annually.

In the Moderately Wet Flow Category, the No Action Alternative and CCS Comparative Baseline show similarly high median values of $47.7-$48 million annually. The Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative has the lowest median value at $44.3-45 million.

Figure TA 15-37
Annual Market Value of Davis Dam Generation: Box Plots



Under the Average Flow Category, the No Action Alternative and CCS Comparative Baseline show similarly high median values of $46-$47 million annually. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Enhanced Coordination Alternatives have the lowest median values, both at $42 million annually.

Under the Dry and Critically Dry Flow Categories, all alternatives display substantially lower median values and vulnerability to low-generation outcomes. Under the Dry Flow Category, the No Action Alternative had the highest median values at $46 million and $44 million, respectively. The action alternatives have similar median values ranging between $38-$42 million.

Under the Critically Dry Flow Category, Maximum Operational Flexibility ($34 million), Representative Preferred ($34 million), and Enhanced Coordination ($35 million) Alternatives had the lowest median values, while the Basic Coordination Alternative had the highest median value of $40 million annually.

Modeling indicates that the Representative Preferred Alternative maintained a median value of $41 million annually in the Dry Flow Category. Under the Critically Dry Flow Category, the Representative Preferred Alternative median value dropped to $34 million annually.

Figure TA 15-38 below shows the annual market value of hydropower generation at Parker Dam, which was calculated by combining modeled annual energy production with an illustrative wholesale electricity price. Annual energy generation is simulated using CRSS, and a fixed fiscal year value per MWhs is applied to determine the dollar values anticipated for each alternative. Results are grouped into five categories by preceding three-year average Lees Ferry natural flow as shown in the figure. Differences in market value between alternatives is due primarily to differences in releases (see **Figure TA 3-27** in **TA 3,** Hydrologic Resources for calendar year releases from Parker Dam).

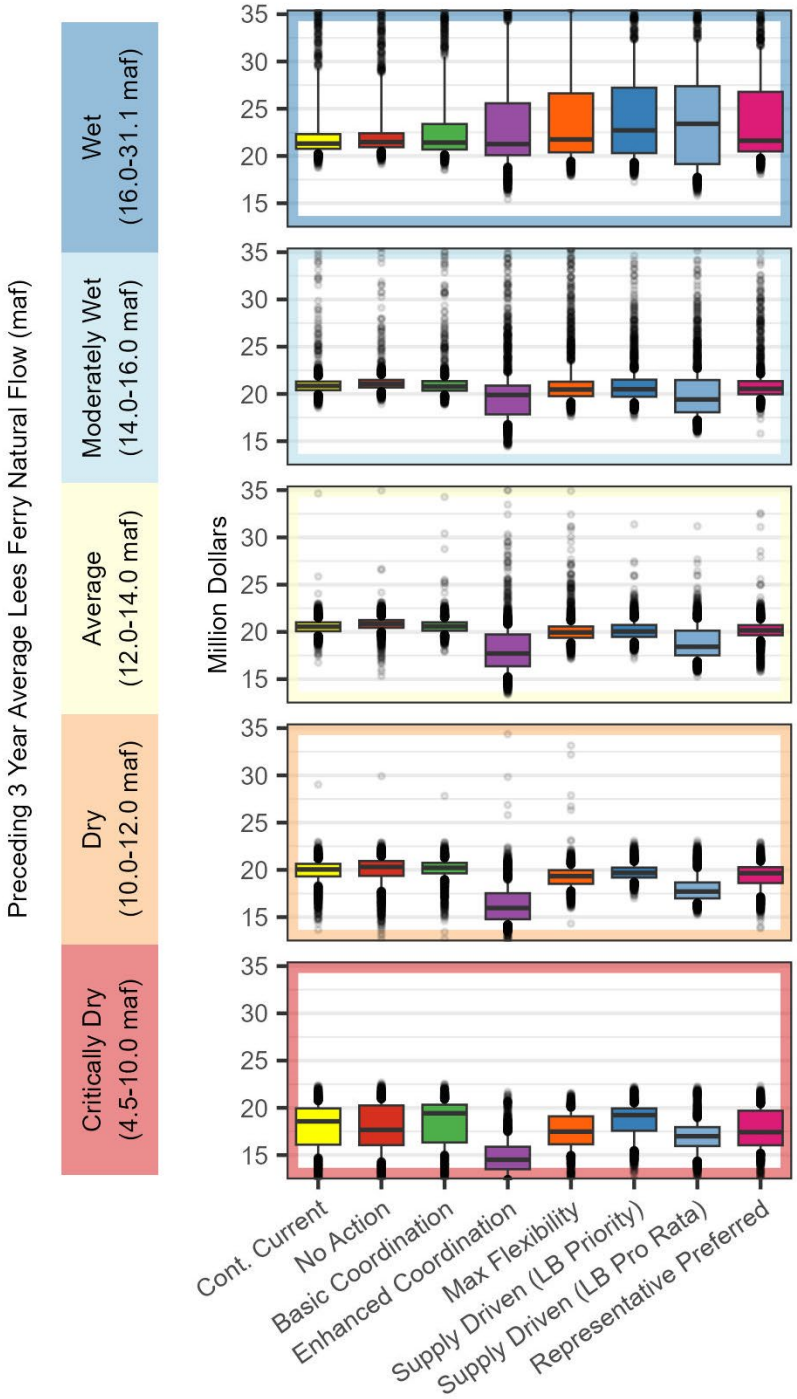
Under the Wet Flow Category, the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative exhibits the largest interquartile range, indicating larger sensitivity to operational differences when hydrologic conditions are favorable, although the median value is $22.7-$23 million annually. The median market values vary little between all alternatives with none falling less than $20 million annually.

Under the Moderately Wet and Average Flow Categories, median market values decline slightly across all alternatives and interquartile ranges narrow, reflecting less variability and sensitivity to hydrologic conditions. Median values across all alternatives range from $18-$21 million annually. Enhanced Coordination and Supply Driven (LB Pro Rata) Alternatives both experience larger interquartile ranges, with 25th percentiles dropping to $16 million and $18 million, respectively.

Under the Dry and Critically Dry Flow Categories, Enhanced Coordination and Supply Driven (LB Pro Rata) Alternatives have noticeably lower median values than the other alternatives, with values of $15 million and $16.9 million, respectively. CCS Comparative Baseline ($18.6-$20 million), as well as No Action ($17.7-$20 million), Basic Coordination ($19.4-$20 million), Supply Driven (LB Priority) ($19.2-$19.7 million), and Representative Preferred ($17.4-$19.6 million) Alternatives generally showed higher median market values across these categories.

Modeling indicates that the Representative Preferred Alternative maintained a median market value of $19.6 million annually across the Dry Flow Category. Under the Critically Dry Flow Category, the Representative Preferred Alternative had a median value of $17.4 million annually.

Figure TA 15-38
Annual Market Value of Parker Dam Generation: Box Plots



Summary of Issue 5 Impacts

Market value generally declined as hydrologic conditions became drier, reflecting lower energy generation across all facilities. The differences among alternatives was greatest at Glen Canyon Dam and Hoover Dam, while Davis Dam and Parker Dam exhibited smaller variations in market value.

For Glen Canyon Dam, the Representative Preferred Alternative achieved the highest market values under wet conditions ($358 million annually), while the Enhanced Coordination ($180-$216 million annually) and Maximum Operational Flexibility ($127-$178 million annually) Alternatives performed best under dry and critically dry conditions, maintaining the highest median values and lowest variability. The No Action Alternative and CCS Comparative Baseline generally produced lower market values and experienced greater variability.

For Hoover Dam the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternative generally produced the highest market values under wet and moderately wet conditions ($195-$277 million annually). Under average, dry, and critically dry conditions, the Enhanced Coordination, Maximum Operational Flexibility, Representative Preferred, and Supply Driven (LB Pro Rata) Alternatives maintained higher median market values and narrower interquartile ranges than the CCS Comparative Baseline and No Action Alternative consistently exhibited lower values with greater variability.

For Davis Dam, under wetter flow conditions, wider interquartile ranges were present in Basic Coordination, Enhanced Coordination, Maximum Operation Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and the Representative Preferred Alternatives. Median values were between $50-$57 million annually. Under moderately wet and average conditions, median values generally range between $41-$489 million annually across all alternatives. Under dry and critically dry conditions, market values declined across all alternatives; however, the Enhanced Coordination Alternative had the lowest value with 25 percent of years falling to $28 million or less, annually.

For Parker Dam, market values exhibited the least variation among alternatives, with most median values ranging between approximately $15-$23 million annually, across all flow categories. Under Dry and Critically Dry Categories, the Enhanced Coordination ($15.5-$16 million) and Supply Driven (LB Pro Rata approach) ($16.9-$17.7 million) Alternatives tended to produce lower median market values than the other alternatives.

Overall, the Representative Preferred and Maximum Operational Flexibility Alternatives generally maintained higher market values and reduced variability under increasingly dry hydrologic conditions, whereas the No Action Alternative and CCS Comparative Baseline were more likely to exhibit lower market values and greater variability, particularly at Glen Canyon and Hoover Dams.

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Technical Appendix 16

Socioeconomics

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
2024 Final SEIS	Near-term Colorado River Operations Final Supplemental Environmental Impact Statement
Basin	Colorado River Basin
CAP	Central Arizona Project
CCS	Continued Current Strategies
cfs	cubic feet per second
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
GCNP	Grand Canyon National Park
GDP	gross domestic product
kaf	thousand acre-feet
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
NPS	National Park Service
NRA	National Recreation Area
NWR	National Wildlife Refuge
PPR	present perfected right
Reclamation	Bureau of Reclamation
SEIS	supplemental environmental impact statement
U.S.	United States

TA 16. Socioeconomics

TA 16.1 Affected Environment

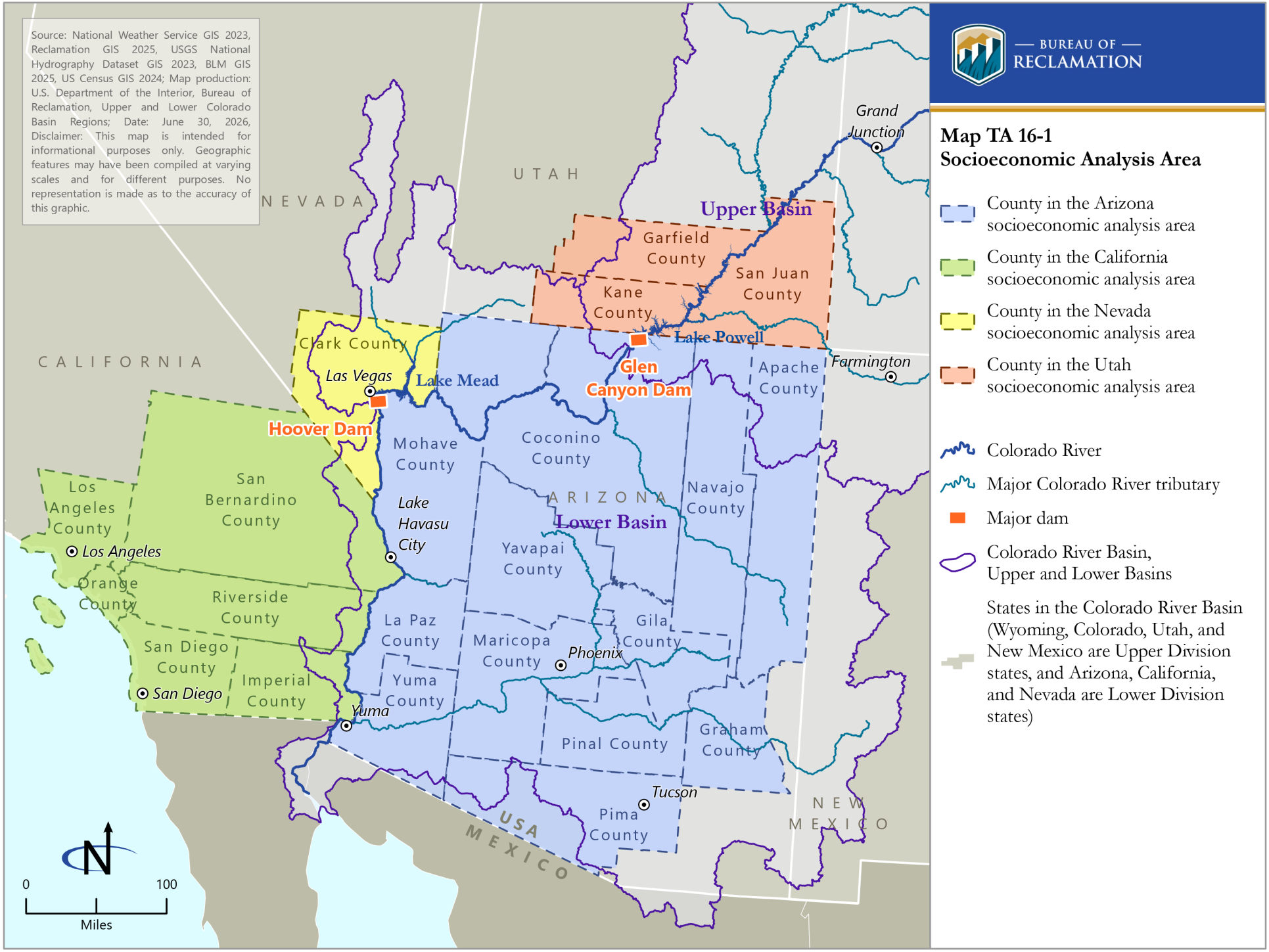
TA 16.1.1 Socioeconomic Analysis Area

The analysis area for the socioeconomic analysis includes counties in Arizona, California, Nevada, and Utah (see **Map TA 16-1** for a map of the socioeconomic analysis area). In **Section TA 16.2.1**, Methodology, in the Impact Analysis Area subsection under the Agriculture, Recreation, and Ecosystem Services and Nonmarket Values subsections, the socioeconomic analysis area is further described as it relates to each issue statement that was analyzed in this technical appendix. The analysis of impacts on economic and social conditions due to changes in agricultural production included Arizona, California, and Nevada. The analysis on economic impacts from changes in recreational use included Arizona, California, Nevada, and Utah. The impact analysis on ecosystem services and nonmarket values included Arizona, California, Nevada, and Utah. The counties and communities that are included in the socioeconomic analysis area are described further below, by state.

The Arizona analysis area consists of Apache, Coconino, Gila, Graham, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, Yavapai, and Yuma Counties. These include counties that are directly adjacent to Lake Powell, Lake Mead, or the mainstream Colorado River; counties in which impacts from Colorado River shortages would likely occur; and counties where tribal reservations affected by Colorado River or Central Arizona Project (CAP) shortages are located.[1] The counties in which measurable mainstream Colorado River or CAP shortages could potentially occur to tribal and non-tribal irrigation entitlement holders, resulting in reductions in agricultural production, are La Paz, Maricopa, Mohave, Pinal, Pima, and Yuma Counties.

Apache, Coconino, Gila, Graham, Navajo, and Yavapai Counties would not experience a water shortage to irrigation entitlement holders attributable to the alternatives; however, they are included in the analysis area because of the ties these counties have to recreation-related economic activity on the Colorado River as well as ties to Indian water rights settlements involving CAP water and non-CAP Colorado River water delivered through the CAP. Please refer to **Table 18-3**, CAP Water Entitlements, in **Section TA 18.1.2**, Water Entitlements, Water Deliveries, and Storage and Conservation Options, in **TA 18**, Indian Trust Assets, for details on tribes with CAP contracts.

[1] See **Section 1.5.1**, Geographic Scope of Scope of the Proposed Federal Action and Affected Regions and Interests, of the Final EIS, for more information on the geographic scope that would be affected by the alternatives analyzed.


Source: National Weather Service GIS 2023, Reclamation GIS 2025, USGS National Hydrography Dataset GIS 2023, BLM GIS 2025, US Census GIS 2024; Map production: U.S. Department of the Interior, Bureau of Reclamation, Upper and Lower Colorado Basin Regions; Date: June 30, 2026, Disclaimer: This map is intended for informational purposes only. Geographic features may have been compiled at varying scales and for different purposes. No representation is made as to the accuracy of this graphic.
BUREAU OF RECLAMATION
Map TA 16-1
Socioeconomic Analysis Area
County in the Arizona socioeconomic analysis area
County in the California socioeconomic analysis area
County in the Nevada socioeconomic analysis area
County in the Utah socioeconomic analysis area
Colorado River
Major Colorado River tributary
Major dam
Colorado River Basin, Upper and Lower Basins
States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)
NEVADA
UTAH
CALIFORNIA
ARIZONA
NEW MEXICO
USA
MEXICO
Upper Basin
Lower Basin
Grand Junction
Garfield County
Kane County
San Juan County
Lake Powell
Glen Canyon Dam
Farmington
Apache County
Clark County
Las Vegas
Lake Mead
Hoover Dam
Mohave County
Coconino County
Navajo County
Lake Havasu City
Yavapai County
Los Angeles County
Los Angeles
San Bernardino County
Orange County
Riverside County
San Diego County
San Diego
Imperial County
La Paz County
Maricopa County
Phoenix
Gila County
Yuma County
Yuma
Pinal County
Graham County
Tucson
Pima County
N
0
100
Miles

The California analysis area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. These counties were selected because they are either directly adjacent to the Colorado River, or they are within the Metropolitan Water District of Southern California service area. Although Ventura County is also in the Metropolitan Water District of Southern California service area, it does not receive any water from the Colorado River; therefore, it is not included in the analysis area.

The Nevada analysis area consists of Clark County. The analysis area was limited to Clark County because Clark County is adjacent to Lake Mead and encompasses the Southern Nevada Water Authority's service area and other individual water providers. Shortages in Nevada would be limited to Southern Nevada Water Authority's service area.

The Utah analysis area consists of Garfield, Kane, and San Juan Counties. Utah will not experience shortages under any alternative, so Utah was not included in the analysis area for the agriculture economic impact analysis in this technical appendix. However, changes in storage at Lake Powell could result in changes in recreation-related expenditures made in these Utah analysis area counties; therefore, the following sections include baseline data for Utah because they relate to economic and social conditions due to changes in recreation.

TA 16.1.2 Baseline Economic Conditions

This section provides an overview of baseline economic conditions related to Colorado River water use with the potential to be affected by water shortages. Baseline data used to inform this section were collected from the United States (U.S.) Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and current, relevant literature. These data are county-level data on employment, labor income, unemployment rates, poverty, and the market value of agricultural production in the analysis areas. The county-level data do not distinguish between water sources that were used in support of the economic conditions presented, which may include a combination of the mainstream Colorado River, CAP, and other water sources.

Arizona

Employment and Personal Income

Table TA 16-1 and **Table TA 16-2**, below, provide an overview for employment by sector for the counties in the analysis area in Arizona in 2010 and 2022, respectively. Full- and part-time employment in Arizona totaled almost 4.3 million jobs in 2022, an increase of approximately 1.1 million jobs from 2010 levels. Farm employment totaled almost 28,000 jobs in 2022 and accounted for 0.6 percent of the total employment in the state; this is a small reduction from the number of jobs and the percentage of the total employment in 2010, at almost 29,000 jobs and 0.9 percent of the total employment.

Table TA 16-1
Arizona Employment by Industry (2010)

Employment	Apache County	Coconino County	Gila County	Graham County	La Paz County	Maricopa County	Mohave County	Navajo County	Pima County	Pinal County	Yavapai Couty	Yuma County	Arizona
Total employment	29,145	76,339	20,545	11,169	7,120	2,128,893	64,093	39,742	476,916	81,029	87,126	79,896	3,181,563
Wage and salary employment	20,108	60,171	14,547	8,771	5,632	1,674,446	47,017	27,588	373,423	55,378	56,921	66,962	2,473,077
Proprietors' employment	9,037	16,168	5,998	2,398	1,488	454,447	17,076	12,154	103,493	25,651	30,205	12,934	708,486
Farm employment (number and percentage of total employment)	5,097	2,014	223	670	254	6,325	529	3,665	1,177	2,147	937	3,152	28,609
	17.5%	2.6%	1.1%	6.0%	3.6%	0.3%	0.8%	9.2%	0.2%	2.6%	1.1%	3.9%	0.9%
Nonfarm employment (number and percentage of total employment)	24,048	74,325	20,322	10,499	6,866	2,122,568	63,564	36,077	475,739	78,882	86,189	76,744	3,152,954
	82.5%	97.4%	98.9%	94.0%	96.4%	99.7%	99.2%	90.8%	99.8%	97.4%	98.9%	96.1%	99.1%
Employment by Industry (Number and Percentage of Total Employment)													
Forestry, fishing, and related	238	229	116	(D)	(D)	2,537	(D)	235	391	616	308	9,444	15,507
	0.8%	0.3%	0.6%	(D)	(D)	0.1%	(D)	0.6%	0.1%	0.8%	0.4%	11.8%	0.5%
Mining, quarrying, and oil and gas extraction	59	220	1,082	(D)	(D)	6,348	592	575	3,241	1,540	1,690	121	17,968
	0.2%	0.3%	5.3%	(D)	(D)	0.3%	0.9%	1.4%	0.7%	1.9%	1.9%	0.2%	0.6%
Utilities	(D)	107	66	72	(D)	8,193	311	57	2,115	294	131	179	12,518
	(D)	0.1%	0.3%	0.6%	(D)	0.4%	0.5%	0.1%	0.4%	0.4%	0.2%	0.2%	0.4%
Construction	1,046	3,144	1,228	(D)	181	109,587	4,051	1,845	22,088	3,380	5,708	3,556	159,505
	3.6%	4.1%	6.0%	(D)	2.5%	5.1%	6.3%	4.6%	4.6%	4.2%	6.6%	4.5%	5.0%
Manufacturing	605	4,084	1,074	265	162	112,507	3,144	735	25,858	3,535	3,422	1,961	158,823
	2.1%	5.3%	5.2%	2.4%	2.3%	5.3%	4.9%	1.8%	5.4%	4.4%	3.9%	2.5%	5.0%
Wholesale trade	(D)	973	249	141	87	87,971	1,076	543	9,731	1,338	2,394	1,437	108,772
	(D)	1.3%	1.2%	1.3%	1.2%	4.1%	1.7%	1.4%	2.0%	1.7%	2.7%	1.8%	3.4%
Retail trade	1,709	8,514	2,349	1,538	1,239	236,685	9,859	4,357	48,909	9,071	11,185	8,411	353,032
	5.9%	11.2%	11.4%	13.8%	17.4%	11.1%	15.4%	11.0%	10.3%	11.2%	12.8%	10.5%	11.1%

Employment	Apache County	Coconino County	Gila County	Graham County	La Paz County	Maricopa County	Mohave County	Navajo County	Pima County	Pinal County	Yavapai Couty	Yuma County	Arizona
Transportation and warehousing	385	1,971	423	158	(D)	64,320	1,774	1,081	9,157	1,887	1,698	1,794	87,237
	1.3%	2.6%	2.1%	1.4%	(D)	3.0%	2.8%	2.7%	1.9%	2.3%	1.9%	2.2%	2.7%
Information	120	595	218	124	29	34,552	1,036	1,249	5,866	785	1,080	662	47,208
	0.4%	0.8%	1.1%	1.1%	0.4%	1.6%	1.6%	3.1%	1.2%	1.0%	1.2%	0.8%	1.5%
Finance and insurance	(D)	1,622	493	266	120	156,658	2,043	867	22,093	2,941	3,390	1,685	194,156
	(D)	2.1%	2.4%	2.4%	1.7%	7.4%	3.2%	2.2%	4.6%	3.6%	3.9%	2.1%	6.1%
Real estate rental and leasing	595	3,236	1,081	330	297	140,169	4,206	1,592	25,055	4,431	6,785	2,555	193,014
	2.0%	4.2%	5.3%	3.0%	4.2%	6.6%	6.6%	4.0%	5.3%	5.5%	7.8%	3.2%	6.1%
Professional, scientific, and technical services	352	3,020	(D)	912	122	147,900	2,301	1,012	32,335	3,575	4,758	2,515	205,097
	1.2%	4.0%	(D)	8.2%	1.7%	6.9%	3.6%	2.5%	6.8%	4.4%	5.5%	3.1%	6.4%
Management of companies and enterprises	38	129	(D)	(D)	32	25,180	(D)	248	3,173	93	138	100	29,569
	0.1%	0.2%	(D)	(D)	0.4%	1.2%	(D)	0.6%	0.7%	0.1%	0.2%	0.1%	0.9%
Administrative, support, and waste management	375	2,138	882	(D)	322	188,443	3,888	1,059	33,965	6,454	3,850	5,498	250,885
	1.3%	2.8%	4.3%	(D)	4.5%	8.9%	6.1%	2.7%	7.1%	8.0%	4.4%	6.9%	7.9%
Educational services	632	951	164	(D)	(D)	51,118	742	979	7,510	1,143	2,536	575	67,392
	2.2%	1.2%	0.8%	(D)	(D)	2.4%	1.2%	2.5%	1.6%	1.4%	2.9%	0.7%	2.1%
Health care and social assistance	2,357	8,752	2,181	1,360	(D)	221,074	8,456	3,564	62,367	6,034	10,131	7,725	340,074
	8.1%	11.5%	10.6%	12.2%	(D)	10.4%	13.2%	9.0%	13.1%	7.4%	11.6%	9.7%	10.7%
Arts, entertainment, and recreation	220	2,687	359	(D)	(D)	45,043	1,013	634	10,802	1,598	2,841	570	66,935
	0.8%	3.5%	1.7%	(D)	(D)	2.1%	1.6%	1.6%	2.3%	2.0%	3.3%	0.7%	2.1%
Accommodation and food services	1,239	11,031	1,487	(D)	(D)	153,423	5,820	3,285	35,864	4,434	6,752	5,531	235,695
	4.3%	14.5%	7.2%	(D)	(D)	7.2%	9.1%	8.3%	7.5%	5.5%	7.7%	6.9%	7.4%
Other services	713	3,254	957	646	326	104,806	4,303	1,848	25,669	4,963	5,835	3,494	160,513
	2.4%	4.3%	4.7%	5.8%	4.6%	4.9%	6.7%	4.6%	5.4%	6.1%	6.7%	4.4%	5.0%
Government and government enterprises	12,581	17,668	5,172	2,763	2,334	226,054	8,661	10,312	89,550	20,770	11,557	18,931	449,054
	43.2%	23.1%	25.2%	24.7%	32.8%	10.6%	13.5%	25.9%	18.8%	25.6%	13.3%	23.7%	14.1%

Source: BEA 2024a

D = not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Table TA 16-2
Arizona Employment by Industry (2022)

Employment	Apache County	Coconino County	Gila County	Graham County	La Paz County	Maricopa County	Mohave County	Navajo County	Pima County	Pinal County	Yavapai County	Yuma County	Arizona
Total employment	26,932	88,910	21,663	14,234	8,161	3,038,704	81,675	43,690	557,893	116,876	112,493	95,822	4,287,595
Wage and salary employment	17,385	67,640	15,362	10,741	6,402	2,307,069	57,889	29,232	415,635	71,285	71,986	76,858	3,206,670
Proprietors' employment	9,547	21,270	6,301	3,493	1,759	731,635	23,786	14,458	142,258	45,591	40,507	18,964	1,080,925
Farm employment (number and percentage of total employment)	5,164	2,088	179	405	434	5,775	479	3,819	1,042	2,051	1,190	3,110	27,735
	19.2%	2.3%	0.8%	2.8%	5.3%	0.2%	0.6%	8.7%	0.2%	1.8%	1.1%	3.2%	0.6%
Nonfarm employment (number and percentage of total employment)	21,768	86,822	21,484	13,829	7,727	3,032,929	81,196	39,871	556,851	114,825	111,303	92,712	4,259,860
	80.8%	97.7%	99.2%	97.2%	94.7%	99.8%	99.4%	91.3%	99.8%	98.2%	98.9%	96.8%	99.4%
Employment by Industry (Number and Percentage of Total Employment)													
Forestry, fishing, and related	(D)	254	125	(D)	(D)	2,678	(D)	(D)	494	569	369	(D)	14,280
	(D)	0.3%	0.6%	(D)	(D)	0.1%	(D)	(D)	0.1%	0.5%	0.3%	(D)	0.3%
Mining, quarrying, and oil and gas extraction	(D)	178	1,029	(D)	88	5,733	469	(D)	3,762	1,313	1,711	(D)	20,295
	(D)	0.2%	4.8%	(D)	1.1%	0.2%	0.6%	(D)	0.7%	1.1%	1.5%	(D)	0.5%
Utilities	(D)	196	70	(D)	11	8,357	418	119	2,064	365	220	157	12,818
	(D)	0.2%	0.3%	(D)	0.1%	0.3%	0.5%	0.3%	0.4%	0.3%	0.2%	0.2%	0.3%
Construction	1,278	4,086	1,374	699	219	197,947	6,958	2,718	29,426	6,691	9,184	5,253	270,022
	4.7%	4.6%	6.3%	4.9%	2.7%	6.5%	8.5%	6.2%	5.3%	5.7%	8.2%	5.5%	6.3%
Manufacturing	249	3,852	1,303	265	293	148,956	3,561	533	30,132	5,641	4,725	3,483	204,725
	0.9%	4.3%	6.0%	1.9%	3.6%	4.9%	4.4%	1.2%	5.4%	4.8%	4.2%	3.6%	4.8%
Wholesale trade	403	1,412	190	(D)	131	102,023	1,827	573	9,631	2,265	2,460	2,108	126,540
	1.5%	1.6%	0.9%	(D)	1.6%	3.4%	2.2%	1.3%	1.7%	1.9%	2.2%	2.2%	3.0%
Retail trade	1,244	8,866	2,398	1,984	1,739	289,783	12,436	4,775	52,938	14,351	13,759	10,107	422,975
	4.6%	10.0%	11.1%	13.9%	21.3%	9.5%	15.2%	10.9%	9.5%	12.3%	12.2%	10.5%	9.9%
Transportation and warehousing	(D)	2,709	486	(D)	179	181,284	3,254	1,592	31,151	7,177	3,292	3,558	240,127
	(D)	3.0%	2.2%	(D)	2.2%	6.0%	4.0%	3.6%	5.6%	6.1%	2.9%	3.7%	5.6%

Employment	Apache County	Coconino County	Gila County	Graham County	La Paz County	Maricopa County	Mohave County	Navajo County	Pima County	Pinal County	Yavapai County	Yuma County	Arizona
Information	114	791	184	76	98	52,979	769	364	7,813	1,138	1,077	531	66,692
	0.4%	0.9%	0.8%	0.5%	1.2%	1.7%	0.9%	0.8%	1.4%	1.0%	1.0%	0.6%	1.6%
Finance and insurance	(D)	2,295	727	513	181	256,443	3,078	1,167	28,136	5,261	5,394	4,265	309,879
	(D)	2.6%	3.4%	3.6%	2.2%	8.4%	3.8%	2.7%	5.0%	4.5%	4.8%	4.5%	7.2%
Real estate rental and leasing	745	4,777	1,271	(D)	346	200,999	5,693	2,007	32,866	7,083	9,524	3,721	272,829
	2.8%	5.4%	5.9%	(D)	4.2%	6.6%	7.0%	4.6%	5.9%	6.1%	8.5%	3.9%	6.4%
Professional, scientific, and technical services	(D)	4,012	892	405	(D)	222,987	3,643	1,350	35,199	5,573	6,610	3,652	289,301
	(D)	4.5%	4.1%	2.8%	(D)	7.3%	4.5%	3.1%	6.3%	4.8%	5.9%	3.8%	6.7%
Management of companies and enterprises	(D)	597	63	(D)	(D)	47,528	295	196	2,996	557	477	408	53,464
	(D)	0.7%	0.3%	(D)	(D)	1.6%	0.4%	0.4%	0.5%	0.5%	0.4%	0.4%	1.2%
Administrative, support, and waste management	477	2,948	733	(D)	194	250,356	4,424	1,518	37,995	8,178	5,989	6,384	322,974
	1.8%	3.3%	3.4%	(D)	2.4%	8.2%	5.4%	3.5%	6.8%	7.0%	5.3%	6.7%	7.5%
Educational services	445	1,280	187	(D)	(D)	70,915	887	824	10,175	2,422	2,950	744	92,109
	1.7%	1.4%	0.9%	(D)	(D)	2.3%	1.1%	1.9%	1.8%	2.1%	2.6%	0.8%	2.1%
Health care and social assistance	2,791	9,792	1,731	1,469	(D)	342,031	9,709	4,640	69,969	7,418	10,981	9,589	476,659
	10.4%	11.0%	8.0%	10.3%	(D)	11.3%	11.9%	10.6%	12.5%	6.3%	9.8%	10.0%	11.1%
Arts, entertainment, and recreation	275	3,260	364	135	(D)	60,822	(D)	629	11,851	2,891	2,774	692	85,991
	1.0%	3.7%	1.7%	0.9%	(D)	2.0%	(D)	1.4%	2.1%	2.5%	2.5%	0.7%	2.0%
Accommodation and food services	1,063	14,645	1,988	1,049	(D)	212,406	8,557	4,067	41,557	7,739	10,622	7,560	317,706
	3.9%	16.5%	9.2%	7.4%	(D)	7.0%	10.5%	9.3%	7.4%	6.6%	9.4%	7.9%	7.4%
Other services	652	3,774	1,011	845	(D)	145,117	5,424	2,061	31,225	7,789	7,869	4,636	214,742
	2.4%	4.2%	4.7%	5.9%	(D)	4.8%	6.6%	4.7%	5.6%	6.7%	7.0%	4.8%	5.0%
Government and government enterprises	10,090	17,098	5,358	3,057	2,017	233,585	8,539	9,828	87,471	20,404	11,316	18,370	445,732
	37.5%	19.2%	24.7%	21.5%	24.7%	7.7%	10.5%	22.5%	15.7%	17.5%	10.1%	19.2%	10.4%

Source: BEA 2024a

D = not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Employment in the analysis area counties represents approximately 98.1 percent of the total employment in Arizona. Farm employment in the 12 counties totaled about 26,000 jobs in 2022 and represented about 0.6 percent of the total employment in the analysis area counties.[2] Farm employment made up a larger percentage of the total employment in Apache and Navajo Counties than in the rest of the counties in the analysis area, with 19.2 percent and 8.7 percent of the total employment, respectively (BEA 2024a). In 2022, employment in the arts, entertainment, and recreation sector totaled approximately 84,000 jobs (or 2.0 percent of the total employment in the analysis area), which was an increase from 2010 jobs by about 27 percent.

Total personal income in Arizona was almost $430.1 billion in 2022, compared with $293.8 billion in 2010 (adjusted to 2022 dollars). Likewise, per capita income increased from approximately $46,000 in 2010 (adjusted to 2022 dollars) to approximately $58,000 in 2022; this is a 27.3 percent increase (see **Table TA 16-3**; BEA 2024b). Arizona farm earnings per farm worker, in 2022, were about $35,000 ($965.1 million in farm earnings divided by 27,735 farm jobs), which was an increase of about $3,000 from 2010 earnings (adjusted to 2022 dollars; BEA 2024a, 2024b).

The total personal income generated in the 12 counties represented 97.9 percent of the state total in 2022. Among the 12 counties, average per capita income ranged from a low of approximately $42,000 per year in Graham County and Navajo County to a high of $63,000 per year in Maricopa County. Only Maricopa and Coconino Counties had per capita income above that of the state of Arizona (about $58,000). In 2022, farm earnings per farm worker, including proprietor's income, in the analysis area ranged from an accounting loss[3] of about $3,000 in Apache County to earnings per worker of about $112,000 in Yuma County (BEA 2024a, 2024b).

Table TA 16-4, Arizona Employment by Industry (2010), displays the annual unemployment rate and the population below poverty. The unemployment rate is a key economic indicator, which can indicate the financial health of an economy; a low rate generally indicates a functioning economy, while a high rate is a concern for the general economy and likely indicates that some individuals in the labor force are in economic distress due to the lack of work and associated income. In 2023, eight of the study area counties in Arizona had annual unemployment rates that were higher than the state unemployment rate of 3.9 percent. Unemployment was notably high in Yuma County, with an unemployment rate of 13.2 percent, which is over three times greater than that of the state of Arizona.

[2] Farm employment does not include employment in other industries that are supported by the farming industry, such as employment in the transportation and warehousing, manufacturing (including food manufacturing), and retail trade (including food and beverage and grocery stores) industries. Changes in water availability that affect the farming industry would also indirectly affect these industries. More information on indirect impacts on employment, labor income, and economic output is discussed in **Section TA 16.2**, Environmental Consequences.

[3] Accounting losses occur when proprietors incur more expenses than the revenues they receive.

Table TA 16-3
2010 and 2022 Arizona Personal Income and Earnings (2022$)

Geographic Area	Year	Personal Income ($1,000s)[1]	Per Capita Personal Income ($)	Earnings by Place of Work ($1,000s)[2]	Wages and Salaries ($1,000s)	Supplements to Wages and Salaries ($1,000s)	Proprietors' Income ($1,000s)	Farm Earnings ($1,000s)[3]	Nonfarm Earnings ($1,000s)
Apache County	2010	2,609,269	36,405	1,414,013	1,022,775	341,461	49,777	-16,648	1,430,661
	2022	2,985,841	45,633	1,258,823	933,078	291,883	33,862	-17,685	1,276,508
Coconino County	2010	6,320,272	46,927	4,242,788	3,002,872	858,815	381,102	7,835	4,234,954
	2022	8,489,905	58,933	5,104,144	3,429,711	831,405	843,028	18,221	5,085,923
Gila County	2010	2,292,299	42,815	1,031,683	733,922	202,274	95,487	-1,627	1,033,310
	2022	2,723,317	50,505	1,151,619	834,614	199,452	117,553	4,440	1,147,179
Graham County	2010	1,220,682	32,868	579,806	415,149	119,880	44,776	21,457	558,349
	2022	1,614,728	41,593	788,260	564,091	144,457	79,712	20,956	767,304
La Paz County	2010	730,733	35,875	350,640	233,038	68,798	48,804	7,817	342,823
	2022	891,281	53,997	438,520	303,349	73,280	61,891	2,279	436,241
Maricopa County	2010	188,035,877	49,196	138,424,028	106,164,387	23,093,967	9,165,674	268,309	138,155,719
	2022	288,842,282	63,461	214,404,981	161,524,726	29,587,729	23,292,526	309,573	214,095,408
Mohave County	2010	7,038,922	35,149	3,104,621	2,145,945	557,828	400,848	4,747	3,099,875
	2022	9,858,399	44,645	4,264,281	2,855,094	609,712	799,475	29,302	4,234,979
Navajo County	2010	3,602,578	33,492	1,871,351	1,341,136	393,864	136,351	9,635	1,861,715
	2022	4,573,766	42,096	2,083,700	1,444,111	385,028	254,561	4,493	2,079,207
Pima County	2010	45,472,764	46,340	29,279,856	20,803,977	5,403,156	3,072,723	53,300	29,226,556
	2022	57,601,036	54,464	33,730,853	24,181,286	5,425,568	4,123,999	38,815	33,692,038
Pinal County	2010	12,272,501	32,462	4,258,204	2,939,244	822,156	496,804	85,827	4,172,376
	2022	21,327,852	45,950	5,769,883	3,853,398	898,204	1,018,281	143,314	5,626,569
Yavapai County	2010	8,281,422	39,265	3,767,437	2,601,263.42	671,921.70	494,252.20	3,424.65	3,764,012.67
	2022	12,784,510	51,921	5,426,215	3,607,595	776,457	1,042,163	22,356	5,403,859
Yuma County	2010	7,434,183	37,768	4,869,064	3,199,051	929,114	740,899	422,731	4,446,333
	2022	9,313,549	44,811	6,007,178	4,013,230	1,047,861	946,087	347,302	5,659,876
Arizona	2010	293,846,986	45,899	198,706,221	148,343,547	34,563,721	15,798,954	912,061	197,794,160
	2022	430,083,534	58,442	285,840,783	211,131,613	41,274,140	33,435,030	965,062	284,875,721

Source: BEA 2024b

[1] Personal income is calculated at the place of residence and includes labor income as well as non-labor income, such as dividends, interest, and rent.

[2] Earnings is calculated at the place of work based on labor income, such as wages and salaries, supplements, and proprietors' income.

[3] Accounting losses in farm earnings occur when proprietors incur more expenses than the revenues they receive.

Across the Arizona analysis area, nine out of the 12 counties had a higher percentage of people living below the poverty level than the state (12.8 percent), with the largest percentage of people below poverty in Apache County (31.2 percent) and Navajo County (24.7 percent). This suggests that economic considerations are important factors for many individuals throughout the analysis area, and management actions that impact economic opportunities and economic conditions could greatly affect the surrounding communities.

Table TA 16-4
Arizona Analysis Area Unemployment and Poverty (2023)

Geographic Area	Unemployment (%)	% Below Poverty
Apache County	7.9	31.2
Coconino County	4.2	17.7
Gila County	4.3	17.8
Graham County	3.7	17.7
La Paz County	4.8	18.4
Maricopa County	3.4	11.3
Mohave County	4.5	16.8
Navajo County	5.7	24.7
Pima County	3.8	14.4
Pinal County	4.1	10.9
Yavapai County	3.6	12.6
Yuma County	13.2	16.5
Arizona	3.9	12.8

Sources: Bureau of Labor Statistics 2023; U.S. Census Bureau 2023a

Agriculture

Agriculture is an important part of the economy in Arizona. Approximately 35 percent of Arizona's land area in 2022 was used for agricultural purposes (on cropland, pastureland, woodland, or other; USDA 2024). In 2022, the market value of agricultural products sold in Arizona contributed $5.2 billion to Arizona's economy. Additional contributions to the economy from agriculture come from the manufacture of crop inputs, crop processing, marketing, and distribution, and agricultural income (Lahmers and Edan 2018). The key crops produced and sold in Arizona include corn, wheat, vegetables, and melons (USDA 2024). The types of crops, amount of water used for agriculture, and the role of agriculture in county economies vary across the state and analysis area. Additional information on irrigated agricultural acreage within the analysis area is provided in **TA 17**, Population and Land Use.

Central and southwestern Arizona farms contribute the largest share of agricultural production in terms of sales values. In 2022, the total market value of agricultural products sold in the Arizona analysis area contributed $4.8 billion to Arizona's economy, which was about 91 percent of the market value of agricultural products sold in the state and about one percent of the Arizona total gross domestic product (GDP). The market value of crops sold in the analysis area (excluding values for La Paz and Yuma Counties to avoid disclosure of confidential information) was about $1.3 billion. Across Maricopa, Pima, and Pinal Counties, the market value of crops sold in 2022 ranged

from about $87.1 million in Pima County to about $742.6 million in Maricopa County (USDA 2024). In 2024, compared with the other analysis area counties, Yuma County and La Paz County had the highest farming output as a percentage of the counties' total economic output, with about 9.2 percent and 7.4 percent of total output coming from the farming industry in La Paz and Yuma Counties, respectively (IMPLAN 2025).

Table TA 16-5 presents a summary of the market value of on-farm agricultural production with respect to county and state GDP. **Table TA 16-6** presents the county-level economic output from the farming industry and the percentage of farming economic output to total county-level output.

Table TA 16-5
Market Value of Agricultural Production in Arizona Analysis Area (2022)

Area	Market Value of Crops Sold ($1,000)	Percentage of Market Value of Crops Sold to County GDP	Percentage of Market Value of Crops Sold to Arizona GDP	Market Value of Agricultural Products Sold ($1,000)
Maricopa County	742,596	0.21	0.16	1,558,021
Pima County	87,130	0.16	0.02	97,973
Pinal County	365,172	3.06	0.08	1,169,581
Total within CAP counties[1]	1,194,898	0.29	0.25	2,825,575
Apache County	3,411	0.12	0.00	16,985
Coconino County	1,437	0.02	0.00	22,593
Gila County	412	0.02	0.00	9,351
La Paz County[2]	(D)	(D)	(D)	270,641
Mohave County	48,846	0.63	0.01	56,558
Navajo County	4,898	0.14	0.00	47,996
Yuma County[2]	(D)	(D)	(D)	1,507,066
Total Arizona analysis area[3]	1,253,902	0.28	0.26	4,756,765

Sources: BEA 2024c; USDA 2024

[1] CAP values are aggregated values for Maricopa, Pima, and Pinal Counties.

[2] D = not shown to avoid disclosure of confidential information.

[3] The totals for the Arizona analysis area do not include data for La Paz and Yuma Counties because the U.S. Department of Agriculture determined the data were too sensitive to disclose.

Table TA 16-6
Farming Economic Output in Arizona Analysis Area (2024)

Area	Total Farming Output (thousand 2025$)	Percentage of County Output
Maricopa County	845,776	0.11
Pima County	56,129	0.05
Pinal County	371,328	1.18
Total within CAP counties[1]	1,273,233	0.14
Apache County	3,719	0.08

Area	Total Farming Output (thousand 2025$)	Percentage of County Output
Coconino County	2,483	0.01
Gila County	1,839	0.03
La Paz County	185,877	9.23
Mohave County	65,350	0.39
Navajo County	6,645	0.09
Yuma County	1,429,958	7.43
Total Arizona analysis area	2,969,103	0.30

Source: IMPLAN 2025

[1] CAP values are aggregated values for Maricopa, Pima, and Pinal Counties.

In 2022, the CAP counties—Maricopa, Pima, and Pinal Counties—accounted for approximately 55 percent of Arizona's harvested acres of hay and haylage crops, 65 percent of the state's harvested acreage of cotton, and 44 percent of the harvested wheat acreage. In 2022, the three western Arizona counties that are located along the Colorado River—Mohave, La Paz, and Yuma Counties—accounted for approximately 33 percent of the statewide harvested hay and haylage acreage, 78 percent of the harvested acres of vegetable crops, and 53 percent of the harvested wheat acres. Yuma County alone accounted for 77 percent of the state's total harvested acres of vegetable crops (USDA 2024).

California

Employment and Personal Income

Table TA 16-7 and **Table TA 16-8**, below, provide an overview for employment by sector for the counties in the analysis area in California in 2010 and 2022, respectively.[4] Full- and part-time employment in California totaled 25.3 million jobs in 2022, an increase of approximately 5.7 million jobs from 2010 levels.

Full- and part-time employment in the six-county analysis area totaled 13.9 million jobs in 2022, representing 55 percent of total California employment. Farm employment in the six counties totaled about 31,000 jobs in 2022 and represented about 0.2 percent of the total employment in the analysis area counties.[5] Farm employment made up a larger percentage of the total employment in Imperial County than in the rest of the counties in the analysis area, with 4.7 percent of the total employment coming from the farm sector in Imperial County (BEA 2024a). In 2022, employment in the arts, entertainment, and recreation sector totaled approximately 395,000 jobs (or 2.8 percent of the total employment in the analysis area), which was an increase from 2010 jobs by about 19 percent.

[4] The analysis does not distinguish between the water source(s) that may support such employment, which may include sources other than, or blended with, mainstream Colorado River water.

[5] Farm employment does not include employment in other industries that are supported by the farming industry, such as employment in the transportation and warehousing, manufacturing (including food manufacturing), and retail trade (including food and beverage and grocery stores) industries. Changes in water availability that affect the farming industry would also indirectly affect these industries. More information on indirect impacts on employment, labor income, and economic output is discussed in **Section TA 16.2**, Environmental Consequences.

Table TA 16-7
California Employment by Industry (2010)

Employment	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Total employment	72,569	5,361,888	1,882,771	806,985	831,765	1,804,100	19,642,544
Wage and salary employment	59,701	4,023,825	1,435,527	582,005	639,579	1,405,940	14,946,351
Proprietors' employment	12,868	1,338,063	447,244	224,980	192,186	398,160	4,696,193
Farm employment (number	3,705	5,410	2,423	7,491	2,755	12,151	232,546
and percentage of total employment)	5.1%	0.1%	0.1%	0.9%	0.3%	0.7%	1.2%
Nonfarm employment	68,864	5,356,478	1,880,348	799,494	829,010	1,791,949	19,409,998
(number and percentage of total employment)	94.9%	99.9%	99.9%	99.1%	99.7%	99.3%	98.8%
Employment by Industry (Number and Percentage of Total Employment)							
Forestry, fishing,	(D)	2,807	1,497	7,556	1,005	2,801	212,035
and related	(D)	0.1%	0.1%	0.9%	0.1%	0.2%	1.1%
Mining, quarrying, and oil	(D)	13,967	5,426	1,967	1,350	4,016	60,312
and gas extraction	(D)	0.3%	0.3%	0.2%	0.2%	0.2%	0.3%
Utilities	485	12,288	4,224	1,811	4,308	7,556	59,332
	0.7%	0.2%	0.2%	0.2%	0.5%	0.4%	0.3%
Construction	1,853	179,611	93,087	55,658	41,158	81,056	865,756
	2.6%	3.3%	4.9%	6.9%	4.9%	4.5%	4.4%
Manufacturing	2,899	399,993	160,589	41,833	50,826	100,816	1,322,647
	4.0%	7.5%	8.5%	5.2%	6.1%	5.6%	6.7%
Wholesale trade	2,187	248,880	95,232	24,772	35,659	50,542	724,352
	3.0%	4.6%	5.1%	3.1%	4.3%	2.8%	3.7%
Retail trade	8,504	486,294	176,906	99,926	96,247	163,881	1,880,137
	11.7%	9.1%	9.4%	12.4%	11.6%	9.1%	9.6%
Transportation	2,478	189,424	31,791	26,524	55,234	29,650	567,941
and warehousing	3.4%	3.5%	1.7%	3.3%	6.6%	1.6%	2.9%
Information	448	232,777	31,550	12,969	7,892	31,710	508,677
	0.6%	4.3%	1.7%	1.6%	0.9%	1.8%	2.6%

Employment	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Finance and insurance	1,504	258,386	128,200	31,148	30,991	83,127	953,934
	2.1%	4.8%	6.8%	3.9%	3.7%	4.6%	4.9%
Real estate rental and leasing	1,748	299,202	131,862	45,325	33,414	100,269	1,033,813
	2.4%	5.6%	7.0%	5.6%	4.0%	5.6%	5.3%
Professional, scientific, and technical services	1,659	436,666	182,266	40,460	37,815	188,902	1,703,247
	2.3%	8.1%	9.7%	5.0%	4.5%	10.5%	8.7%
Management of companies and enterprises	257	58,381	25,158	3,384	6,176	18,993	207,094
	0.4%	1.1%	1.3%	0.4%	0.7%	1.1%	1.1%
Administrative, support, and waste management	3,201	353,393	156,216	59,039	69,840	110,621	1,248,610
	4.4%	6.6%	8.3%	7.3%	8.4%	6.1%	6.4%
Educational services	257	144,272	37,274	10,599	13,530	40,478	439,531
	0.4%	2.7%	2.0%	1.3%	1.6%	2.2%	2.2%
Health care and social assistance	8,420	531,002	162,038	71,692	86,653	150,232	1,868,599
	11.6%	9.9%	8.6%	8.9%	10.4%	8.3%	9.5%
Arts, entertainment, and recreation	354	198,153	55,081	18,853	12,728	45,621	538,952
	0.5%	3.7%	2.9%	2.3%	1.5%	2.5%	2.7%
Accommodation and food services	3,554	349,498	143,507	64,109	53,619	139,829	1,369,985
	4.9%	6.5%	7.6%	7.9%	6.4%	7.8%	7.0%
Other services	3,832	360,755	102,584	55,348	52,257	103,313	1,166,383
	5.3%	6.7%	5.4%	6.9%	6.3%	5.7%	5.9%
Government and government enterprises	18,455	600,729	155,860	126,521	138,308	338,536	2,678,661
	25.4%	11.2%	8.3%	15.7%	16.6%	18.8%	13.6%

Source: BEA 2024a

D = not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Table TA 16-8
California Employment by Industry (2022)

Employment	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Total employment	84,886	6,805,191	2,386,649	1,199,971	1,193,681	2,270,595	25,300,974
Wage and salary employment	69,201	4,843,059	1,758,050	859,500	903,758	1,713,934	18,814,316
Proprietors' employment	15,685	1,962,132	628,599	340,471	289,923	556,661	6,486,658
Farm employment (number	3,967	4,197	1,271	7,156	2,466	11,749	228,186
and percentage of total employment)	4.7%	0.1%	0.1%	0.6%	0.2%	0.5%	0.9%
Nonfarm employment	80,919	6,800,994	2,385,378	1,192,815	1,191,215	2,258,846	25,072,788
(number and percentage of total employment)	95.3%	99.9%	99.9%	99.4%	99.8%	99.5%	99.1%
Employment by Industry (Number and Percentage of Total Employment)							
Forestry, fishing,	6,356	2,862	1,115	6,845	1,201	2,763	259,767
and related	7.5%	0.0%	0.0%	0.6%	0.1%	0.1%	1.0%
Mining, quarrying, and oil	421	6,494	2,850	1,674	1,603	2,088	36,926
and gas extraction	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Utilities	522	13,497	3,504	1,910	4,112	5,984	67,516
	0.6%	0.2%	0.1%	0.2%	0.3%	0.3%	0.3%
Construction	2,583	247,498	134,674	100,111	61,113	115,692	1,259,662
	3.0%	3.6%	5.6%	8.3%	5.1%	5.1%	5.0%
Manufacturing	2,572	347,301	161,360	50,990	60,001	125,914	1,419,413
	3.0%	5.1%	6.8%	4.2%	5.0%	5.5%	5.6%
Wholesale trade	2,385	253,705	94,090	34,573	49,500	59,274	773,657
	2.8%	3.7%	3.9%	2.9%	4.1%	2.6%	3.1%
Retail trade	9,800	538,484	191,282	124,022	116,117	180,091	2,090,805
	11.5%	7.9%	8.0%	10.3%	9.7%	7.9%	8.3%
Transportation	3,939	412,112	78,540	118,550	177,757	92,798	1,474,413
and warehousing	4.6%	6.1%	3.3%	9.9%	14.9%	4.1%	5.8%
Information	322	297,427	34,274	9,851	8,061	31,637	727,797
	0.4%	4.4%	1.4%	0.8%	0.7%	1.4%	2.9%

Employment	Imperial County	Los Angeles County	Orange County	Riverside County	San Bernardino County	San Diego County	California
Finance and insurance	2,053	354,030	179,340	49,195	43,147	116,913	1,318,004
	2.4%	5.2%	7.5%	4.1%	3.6%	5.1%	5.2%
Real estate rental and leasing	2,264	458,500	180,924	61,940	48,684	133,935	1,454,721
	2.7%	6.7%	7.6%	5.2%	4.1%	5.9%	5.7%
Professional, scientific, and technical services	2,184	560,569	232,574	56,146	50,533	247,892	2,231,632
	2.6%	8.2%	9.7%	4.7%	4.2%	10.9%	8.8%
Management of companies and enterprises	187	79,182	45,272	4,747	5,669	28,457	284,267
	0.2%	1.2%	1.9%	0.4%	0.5%	1.3%	1.1%
Administrative, support, and waste management	3,625	425,270	202,696	86,326	94,572	143,628	1,581,853
	4.3%	6.2%	8.5%	7.2%	7.9%	6.3%	6.3%
Educational services	477	174,096	56,410	15,397	16,960	48,273	554,586
	0.6%	2.6%	2.4%	1.3%	1.4%	2.1%	2.2%
Health care and social assistance	11,607	890,342	243,499	136,687	140,876	231,189	2,942,827
	13.7%	13.1%	10.2%	11.4%	11.8%	10.2%	11.6%
Arts, entertainment, and recreation	381	231,016	72,196	23,911	15,433	51,915	617,031
	0.4%	3.4%	3.0%	2.0%	1.3%	2.3%	2.4%
Accommodation and food services	4,667	462,052	179,676	96,865	79,767	177,272	1,775,446
	5.5%	6.8%	7.5%	8.1%	6.7%	7.8%	7.0%
Other services	4,465	438,487	128,353	77,159	70,526	124,990	1,423,034
	5.3%	6.4%	5.4%	6.4%	5.9%	5.5%	5.6%
Government and government enterprises	20,109	608,070	162,749	135,916	145,583	338,141	2,779,431
	23.7%	8.9%	6.8%	11.3%	12.2%	14.9%	11.0%

Source: BEA 2024a

Total personal income in California was approximately $3.0 trillion in 2022, compared with about $2.2 trillion in 2010 (adjusted for inflation to 2022 dollars). Statewide per capita income also increased from approximately $59,000 in 2010 (adjusted to 2022 dollars) to approximately $77,000 in 2022 (BEA 2024b; see **Table TA 16-9**). In 2022, California farm earnings per farm worker were about $70,000 ($16.0 billion in farm earnings divided by about 228,000 farm jobs), which was a decrease of about $7,000 from 2010 earnings (adjusted to 2022 dollars; BEA 2024a, 2024b).

The total personal income generated in the six analysis area counties represented 48.9 percent of the state total in 2022. Among the six counties, average per capita income ranged from a low of approximately $45,000 per year in Imperial County to a high of $84,000 per year in Orange County. Only Orange County had per capita income above that of the state of California (about $77,000 in 2022). In 2022, farm earnings per farm worker in the analysis area ranged from about $42,000 in San Diego County to about $147,000 in Imperial County (BEA 2024a, 2024b).

Table TA 16-10, Unemployment and Poverty, displays the annual unemployment rate and the percentage of the population living below poverty. In California, all counties excluding Imperial and Los Angeles Counties had 2023 annual unemployment rates below the state annual unemployment rate of 4.8 percent. Unemployment was notably high in Imperial County, with an unemployment rate of 17.3 percent, which is over 3 times greater than that of the state of California.

Across the California analysis area, half of the counties—Imperial, Los Angeles, and San Bernardino Counties—had a higher percentage of people living below the poverty level than the state (12.0 percent). The largest percentage of people below poverty was in Imperial County (19.6 percent). This suggests that economic considerations are important factors, especially in these counties with high percentages of people living below poverty. Management actions that impact economic opportunities and economic conditions could affect the surrounding communities in these counties.

Agriculture

Approximately 24 percent of California's land area in 2022 was used for agricultural purposes (on cropland, pastureland, woodland, or other; USDA 2024). In 2022, the market value of agricultural products sold in California contributed approximately $59 billion to the statewide economy (USDA 2024). The types of crops, amount of water used for agriculture, and the role of agriculture in county economics vary across the state and analysis area. Additional information on irrigated agricultural acreage within the analysis area is provided in **TA 17**, Population and Land Use.

In 2022, the total market value of agricultural products sold in the California analysis area contributed $6.1 billion to California's economy. The market value of crops sold in the analysis area was about $4.7 billion, ranging from about $69.5 million in Orange County to about $2.2 billion in Imperial County (USDA 2024). In 2024, compared with other counties in the analysis area, Imperial County had the highest farming output as a percentage of the county's total economic output, with 15.5 percent of total economic output coming from the farming industry (IMPLAN 2025). **Table TA 16-11** presents a summary of the market value of on-farm agricultural production with respect to county and state GDP. **Table TA 16-12** presents the county-level economic output from the farming industry and the percentage of farming economic output to total county-level output.

Table TA 16-9
2010 and 2022 California Personal Income and Earnings (2022$)

Geographic Area	Year	Personal Income ($1,000s)[1]	Per Capita Personal Income ($)	Earnings by Place of Work ($1,000s)[2]	Wages and Salaries ($1,000s)	Supplements to Wages and Salaries ($1,000s)	Proprietors' Income ($1,000s)	Farm Earnings ($1,000s)	Nonfarm Earnings ($1,000s)
Imperial County	2010	6,913,837	39,579	4,965,502	2,896,362	997,334	1,071,806	637,013	4,328,489
	2022	8,075,656	45,188	5,545,837	3,539,261	1,131,471	875,105	582,341	4,963,496
Los Angeles County	2010	571,262,353	58,157	439,310,025	300,244,372	70,443,822	68,621,832	254,816	439,055,210
	2022	720,740,528	74,142	528,971,677	388,176,660	80,851,366	59,943,651	212,840	528,758,837
Orange County	2010	199,435,828	66,110	152,270,377	105,862,790	23,550,515	22,857,071	158,606	152,111,771
	2022	263,290,135	83,553	188,481,620	137,331,567	27,686,976	23,463,077	75,693	188,405,927
Riverside County	2010	92,596,623	42,088	48,434,234	31,451,692	9,018,065	7,964,477	456,367	47,977,867
	2022	127,195,983	51,415	69,321,008	49,411,833	11,980,844	7,928,331	416,727	68,904,281
San Bernardino County	2010	81,631,592	40,003	52,124,985	36,642,144	10,488,171	4,994,669	196,452	51,928,532
	2022	108,081,645	49,270	74,624,680	53,932,299	13,234,262	7,458,119	181,780	74,442,900
San Diego County	2010	185,043,527	59,645	138,585,701	100,107,049	25,985,297	12,493,354	798,029	137,787,672
	2022	243,506,541	74,326	178,214,544	134,153,290	30,704,869	13,356,385	490,452	177,724,092
California	2010	2,187,979,553	58,624	1,611,764,720	1,105,813,512	265,592,922	240,358,285	17,899,555	1,593,865,165
	2022	3,006,647,281	77,036	2,168,542,286	1,607,341,273	323,041,105	238,159,908	16,004,335	2,152,537,951

Source: BEA 2024b

[1] Personal income is calculated at the place of residence and includes labor income as well as non-labor income, such as dividends, interest, and rent.

[2] Earnings is calculated at the place of work based on labor income, such as wages and salaries, supplements, and proprietors' income.

Table TA 16-10
California Analysis Area Unemployment and Poverty (2023)

Geographic Area	Unemployment (%)	% Below Poverty
Imperial County	17.3	19.6
Los Angeles County	5.0	13.6
Orange County	3.6	9.5
Riverside County	4.8	11.1
San Bernardino County	4.7	13.6
San Diego County	3.9	10.4
California	4.8	12.0

Source: Bureau of Labor Statistics 2023

Table TA 16-11
Market Value of Agricultural Production in California Analysis Area (2022)

Area	Market Value of Crops Sold ($1,000)	Percentage of Market Value of Crops Sold to County GDP	Percentage of Market Value of Crops Sold to Arizona GDP	Market Value of Agricultural Products Sold ($1,000)
Imperial County	2,236,942	20.22	0.06	3,046,146
Los Angeles County	177,940	0.02	0.00	199,849
Orange County	69,533	0.02	0.00	70,707
Riverside County	1,113,260	0.96	0.03	1,273,498
San Bernardino County	99,258	0.08	0.00	457,547
San Diego County	1,004,974	0.34	0.03	1,092,921
Total California analysis area	4,701,907	0.27	0.02	6,140,668

Sources: BEA 2024c; USDA 2024

Table TA 16-12
Farming Economic Output in California Analysis Area (2024)

Area	Total Farming Output (thousand 2025$)	Percentage of County Output
Imperial County	3,051,320	15.50
Los Angeles County	216,001	0.01
Orange County	109,134	0.02
Riverside County	1,391,224	0.59
San Bernardino County	136,645	0.05
San Diego County	1,338,263	0.23
Total California analysis area	6,242,586	0.18

Source: IMPLAN 2025

The key crops in the California analysis area include hay, vegetables, and wheat. In 2022, the California analysis area counties accounted for approximately 30 percent of California's harvested acres of hay and haylage crops, 16 percent of the state's harvested acreage of vegetables, and 35 percent of the harvested wheat acreage (USDA 2024).

Nevada

Employment and Personal Income

Table TA 16-13, below, provides an overview for employment by sector for Clark County and the state of Nevada in 2010 and 2022. Full- and part-time employment in Nevada totaled almost 2.1 million jobs in 2022, an increase of approximately 584,000 jobs from 2010 levels. In 2022, employment in the arts, entertainment, and recreation sector totaled almost 62,000 jobs, or approximately 3 percent of the state's total employment. Farm employment represented only 0.3 percent of the total employment, with a little more than 5,000 jobs.

Full- and part-time employment in Clark County totaled about 1.5 million jobs in 2022; this is an increase of approximately 466,000 jobs from 2010. Total employment in Clark County represented almost 74 percent of the total employment in Nevada. In 2022, employment in the arts, entertainment, and recreation sector totaled almost 47,000 jobs, or 3.1 percent of the total employment in the county. Farm employment represented less than 0.1 percent of the total employment, with a little more than 400 jobs (see **Table TA 16-13**).[6]

Table TA 16-13
Nevada Employment by Industry (2010 and 2022)

Employment	Clark County		Nevada	
	2010	2022	2010	2022
Total employment	1,057,024	1,523,197	1,478,082	2,061,871
Wage and salary employment	834,301	1,120,039	1,153,906	1,528,778
Proprietors' employment	222,723	403,158	324,176	533,093
Farm employment (number and	384	437	5,354	5,208
percentage of total employment)	0.0%	0.0%	0.4%	0.3%
Nonfarm employment (number and	1,056,640	1,522,760	1,472,728	2,056,663
percentage of total employment)	100.0%	100.0%	99.6%	99.7%
Employment by Industry (Number and Percentage of Total Employment)				
Forestry, fishing,	330	491	1,585	2,214
and related	0.0%	0.0%	0.1%	0.1%
Mining, quarrying, and	2,389	1,726	17,016	19,165
oil and gas extraction	0.2%	0.1%	1.2%	0.9%
Utilities	3,015	2,899	4,544	4,612
	0.3%	0.2%	0.3%	0.2%

[6] Farm employment does not include employment in other industries that are supported by the farming industry, such as employment in the transportation and warehousing, manufacturing (including food manufacturing), and retail trade (including food and beverage and grocery stores) industries. Changes in water availability that affect the farming industry would also indirectly affect these industries. More information on indirect impacts on employment, labor income, and economic output is discussed in **Section TA 16.2**, Environmental Consequences.

Employment	Clark County		Nevada	
	2010	2022	2010	2022
Construction	55,382	93,558	75,643	129,422
	5.2%	6.1%	5.1%	6.3%
Manufacturing	21,605	32,929	41,667	71,259
	2.0%	2.2%	2.8%	3.5%
Wholesale trade	24,620	32,949	37,489	48,807
	2.3%	2.2%	2.5%	2.4%
Retail trade	109,280	141,831	152,355	191,956
	10.3%	9.3%	10.3%	9.3%
Transportation and warehousing	36,634	115,664	53,212	153,001
	3.5%	7.6%	3.6%	7.4%
Information	13,000	19,593	17,693	25,517
	1.2%	1.3%	1.2%	1.2%
Finance and insurance	61,578	95,406	83,043	122,182
	5.8%	6.3%	5.6%	5.9%
Real estate rental and leasing	66,955	95,228	94,363	130,455
	6.3%	6.3%	6.4%	6.3%
Professional, scientific, and technical services	56,485	88,272	81,695	121,060
	5.3%	5.8%	5.5%	5.9%
Management of companies and enterprises	16,574	31,130	21,739	37,971
	1.6%	2.0%	1.5%	1.8%
Administrative, support, and waste management	72,349	116,287	95,138	146,587
	6.8%	7.6%	6.4%	7.1%
Educational services	9,889	18,131	13,960	23,945
	0.9%	1.2%	0.9%	1.2%
Health care and social assistance	75,170	127,645	109,647	170,804
	7.1%	8.4%	7.4%	8.3%
Arts, entertainment, and recreation	32,432	46,868	46,698	61,968
	3.1%	3.1%	3.2%	3.0%
Accommodation and food services	242,559	263,173	290,879	314,012
	22.9%	17.3%	19.7%	15.2%
Other services	46,024	75,466	65,246	99,734
	4.4%	5.0%	4.4%	4.8%
Government and government enterprises	110,370	123,514	169,116	181992
	10.4%	8.1%	11.4%	8.8%

Source: BEA 2024a

Total personal income in Nevada was approximately $197.3 billion in 2022, compared with about $136.9 billion in 2010 (adjusted for inflation to 2022 dollars). Statewide per capita income increased from approximately $51,000 in 2010 (adjusted to 2022 dollars) to approximately $62,000 in 2022 (BEA 2024b; see **Table TA 16-14**). In 2022, Nevada farm earnings per farm worker were about $34,000 ($177.9 million in farm earnings divided by 5,208 farm jobs), which was a decrease of about $3,000 from 2010 earnings (adjusted to 2022 dollars; BEA 2024a, 2024b).

The total personal income in Clark County represented 69.6 percent of the state total in 2022. In 2022, the per capita income in Clark County was approximately $59,000, which was slightly lower than the per capita income for the state. Farm earnings were not a major portion of total earnings in Clark County, with less than 0.1 percent of earnings coming from the farm industry (BEA 2024b; see **Table TA 16-14**).

Table TA 16-14
2010 and 2022 Nevada Personal Income and Earnings (2022$)

Income/Earnings	Clark County		Nevada	
	2010	2022	2010	2022
Personal income ($1,000s)[1]	94,708,479	137,403,632	136,919,356	197,290,898
Per capita personal income ($)	48,526	59,150	50,674	62,085
Earnings by place of work ($1,000s)[2]	67,818,266	94,377,994	96,935,404	131,549,693
Wages and salaries ($1,000s)	49,631,728	69,754,265	68,438,673	96,490,818
Supplements to wages and salaries ($1,000s)	12,230,529	14,242,958	17,494,798	20,144,396
Proprietors' income ($1,000s)	5,956,009	10,380,771	11,001,933	14,914,479
Farm earnings ($1,000s)	5,080	491	196,486	177,935
Nonfarm earnings ($1,000s)	67,813,186	94,377,503	96,738,917	131,371,758

Source: BEA 2024b

[1] Personal income is calculated at the place of residence and includes labor income as well as non-labor income, such as dividends, interest, and rent.

[2] Earnings is calculated at the place of work based on labor income, such as wages and salaries, supplements, and proprietors' income.

Table TA 16-15, below, displays the annual unemployment rate and the percentage of the population below poverty. In 2023, the Nevada analysis area—Clark County—had an annual unemployment rate (5.4 percent) that was slightly higher than the state annual unemployment rate (5.1 percent). Similarly, the percentage of people living below poverty in Clark County (13.2 percent) was slightly higher than the percentage for Nevada (12.6 percent).

Table TA 16-15
Nevada Analysis Area Unemployment and Poverty (2023)

Geographic Area	Unemployment (%)	% Below Poverty
Clark County	5.4	13.2
Nevada	5.1	12.6

Sources: Bureau of Labor Statistics 2023; U.S. Census Bureau 2023a

Agriculture

Approximately 8.4 percent of Nevada's land area in 2022 was used for agricultural purposes (on cropland, pastureland, woodland, or other; USDA 2024). In 2022, the market value of agricultural

products sold in Nevada contributed nearly $1 billion to the statewide economy. Additional information on irrigated agricultural acreage within the analysis area is provided in **TA 17**, Population and Land Use.

Utah

Employment and Personal Income

Table TA 16-16, below, provides an overview for employment by sector for the Utah analysis area in 2010 and 2022. Full- and part-time employment in Utah totaled almost 2.4 jobs in 2022, an increase of approximately 747,000 jobs from 2010 levels. In 2022, employment in the arts, entertainment, and recreation sector totaled almost 51,000 jobs, or approximately 2.2 percent of the total employment in the state.

Full- and part-time employment in the Utah analysis area totaled about 17,000 jobs in 2022, an increase of approximately 3,000 jobs from 2010. Total employment in the analysis area represented approximately 1.0 percent of the total employment in Utah. In 2022, employment in the arts, entertainment, and recreation sector totaled approximately 400 jobs (or 2.6 percent of the total employment in the analysis area) and represented 6.0 percent of employment in Kane County (see **Table TA 16-16**).

Total personal income in Utah was approximately $205.5 billion in 2022, compared with about $120.9 billion in 2010 (adjusted for inflation to 2022 dollars). Statewide per capita income increased from approximately $44,000 in 2010 (adjusted to 2022 dollars) to approximately $61,000 in 2022 (BEA 2024b; see **Table TA 16-17**).

The total personal income in the analysis area represented 0.6 percent of the state total in 2022. Among the counties in the analysis area, average per capita income ranged from a low of approximately $37,000 per year in San Juan County to a high of $52,000 per year in Garfield County. All counties in the analysis area had per capita income below that of the state of Utah (about $61,000 in 2022; BEA 2024b; see **Table TA 16-17**).

Table TA 16-18, below, displays the annual unemployment rate and the percentage of the population below poverty. In 2023 in the Utah analysis area, all the counties had a higher annual unemployment rate and percentage of population living below poverty than the state of Utah. This suggests that economic considerations are important factors for many individuals throughout the analysis area, and management actions that impact economic opportunities and economic conditions could greatly affect the surrounding communities.

Table TA 16-16
Utah Employment by Industry (2010 and 2022)

Employment	Garfield County		Kane County		San Juan County		Utah	
	2010	2022	2010	2022	2010	2022	2010	2022
Total employment	3,432	3,907	4,376	6,101	6,310	6,836	1,620,793	2,367,996
Wage and salary employment	2,505	2,733	3,122	4,214	4,566	4,630	1,235,032	1,759,886
Proprietors' employment	927	1,174	1,254	1,887	1,744	2,206	385,761	608,110
Farm employment	293	289	159	169	724	715	20,007	21,081
(number and percentage of total employment)	8.5%	7.4%	3.6%	2.8%	11.5%	10.5%	1.2%	0.9%
Nonfarm employment	3,139	3,618	4,217	5,932	5,586	6,121	1,600,786	2,346,915
(number and percentage of total employment)	91.5%	92.6%	96.4%	97.2%	88.5%	89.5%	98.8%	99.1%
Employment by Industry (Number and Percentage of Total Employment)								
Forestry, fishing, and related	(D)	(D)	(D)	(D)	39	88	3,314	4,704
	(D)	(D)	(D)	(D)	0.6%	1.3%	0.2%	0.2%
Mining, quarrying, and oil and gas extraction	(D)	(D)	(D)	(D)	423	331	14,664	13,730
	(D)	(D)	(D)	(D)	6.7%	4.8%	0.9%	0.6%
Utilities	(D)	34	(D)	(D)	(D)	(D)	4,276	5,064
	(D)	0.9%	(D)	(D)	(D)	(D)	0.3%	0.2%
Construction	137	148	214	332	370	345	91,001	166,041
	4.0%	3.8%	4.9%	5.4%	5.9%	5.0%	5.6%	7.0%
Manufacturing	66	64	(D)	(D)	155	112	118,124	160,756
	1.9%	1.6%	(D)	(D)	2.5%	1.6%	7.3%	6.8%
Wholesale trade	48	44	(D)	47	(D)	(D)	49,833	65,904
	1.4%	1.1%	(D)	0.8%	(D)	(D)	3.1%	2.8%
Retail trade	236	300	456	587	404	440	172,249	235,054
	6.9%	7.7%	10.4%	9.6%	6.4%	6.4%	10.6%	9.9%

Employment	Garfield County		Kane County		San Juan County		Utah	
	2010	2022	2010	2022	2010	2022	2010	2022
Transportation and warehousing	(D)	61	76	(D)	80	(D)	50,898	105,686
	(D)	1.6%	1.7%	(D)	1.3%	(D)	3.1%	4.5%
Information	(D)	156	28	47	(D)	(D)	34,346	54,369
	(D)	4.0%	0.6%	0.8%	(D)	(D)	2.1%	2.3%
Finance and insurance	59	74	126	117	114	151	111,560	174,506
	1.7%	1.9%	2.9%	1.9%	1.8%	2.2%	6.9%	7.4%
Real estate rental and leasing	95	177	271	584	(D)	(D)	93,563	154,826
	2.8%	4.5%	6.2%	9.6%	(D)	(D)	5.8%	6.5%
Professional, scientific, and technical services	53	(D)	124	219	(D)	167	107,012	194,639
	1.5%	(D)	2.8%	3.6%	(D)	2.4%	6.6%	8.2%
Management of companies and enterprises	0	35	0	39	(D)	(D)	22,683	36,775
	0.0%	0.9%	0.0%	0.6%	(D)	(D)	1.4%	1.6%
Administrative, support, and waste management	(D)	(D)	114	234	190	(D)	89,810	121,592
	(D)	(D)	2.6%	3.8%	3.0%	(D)	5.5%	5.1%
Educational services	(D)	(D)	(D)	31	(D)	167	48,952	77,750
	(D)	(D)	(D)	0.5%	(D)	2.4%	3.0%	3.3%
Health care and social assistance	(D)	(D)	(D)	201	(D)	919	137,119	193,936
	(D)	(D)	(D)	3.3%	(D)	13.4%	8.5%	8.2%
Arts, entertainment, and recreation	(D)	64	97	369	80	(D)	34,472	51,311
	(D)	1.6%	2.2%	6.0%	1.3%	(D)	2.1%	2.2%
Accommodation and food services	(D)	1,127	876	1,208	622	(D)	99,679	145,448
	(D)	28.8%	20.0%	19.8%	9.9%	(D)	6.2%	6.1%
Other services	117	150	623	727	295	(D)	82,781	111,237
	3.4%	3.8%	14.2%	11.9%	4.7%	(D)	5.1%	4.7%
Government and government enterprises	613	560	740	783	1,691	1,687	234,450	273,587
	17.9%	14.3%	16.9%	12.8%	26.8%	24.7%	14.5%	11.6%

Source: BEA 2024a

D = not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.

Table TA 16-17
2010 and 2022 Utah Personal Income and Earnings (2022$)

Income/Earnings	Garfield County		Kane County		San Juan County		Utah	
	2010	2022	2010	2022	2010	2022	2010	2022
Personal income ($1,000s)[1]	200,913	273,047	292,876	421,930	434,479	526,823	120,869,769	205,519,377
Per capita personal income ($)	38,659	51,930	40,633	51,436	29,322	36,570	43,538	60,782
Earnings by place of work ($1,000s)[2]	132,965	173,287	170,158	268,139	277,096	319,986	90,872,067	148,445,176
Wages and salaries ($1,000s)	96,926	128,996	121,971	186,110	204,063	214,016	67,410,631	108,895,737
Supplements to wages and salaries ($1,000s)	28,391	27,523	33,009	40,507	62,030	59,217	16,534,956	22,614,907
Proprietors' income ($1,000s)	7,648	16,768	15,179	41,522	11,004	46,753	6,926,480	16,934,532
Farm earnings ($1,000s)[3]	-1,634	13,149	540	3,590	-2,808	6,216	295,906	784,034
Nonfarm earnings ($1,000s)	134,599	160,138	169,619	264,549	279,904	313,770	90,576,160	147,661,142

Source: BEA 2024b

[1] Personal income is calculated at the place of residence and includes labor income as well as non-labor income, such as dividends, interest, and rent.

[2] Earnings is calculated at the place of work based on labor income, such as wages and salaries, supplements, and proprietors' income.

[3] Accounting losses in farm earnings occur when proprietors incur more expenses than the revenues they receive.

Table TA 16-18
Utah Analysis Area Unemployment and Poverty (2023)

Geographic Area	Unemployment	% Below Poverty
Garfield County	7.8	11.1
Kane County	3.2	10.4
San Juan County	3.8	18.4
Utah	2.7	8.6

Sources: Bureau of Labor Statistics 2023; U.S. Census Bureau 2023a

TA 16.1.3 Economic Contributions from Recreational Use

As discussed in **TA 14**, Recreation, recreational activities with the potential to be affected by proposed management include recreation such as boating, camping, and hiking on and adjacent to reservoirs at Lake Powell and Lake Mead, as well as river-based recreation downstream in Glen Canyon and Grand Canyon. Information is also included on wildlife refuges on the Colorado River because the alternatives may affect these refuges.

When visitors recreate on lakes or rivers, the dollars they spend on purchases, such as lodging, gas, food, and outdoor equipment, support local and regional economic contributions, including direct, indirect, and induced jobs; labor income; and economic output.[7] Direct economic contributions occur when businesses sell goods and services to area visitors, such as outfitter services. Indirect economic contributions are additional jobs and economic activity supported when businesses purchase supplies and services from other local businesses, such as supplies used by outfitter businesses. Induced economic contributions occur when employees use their income to purchase goods and services in the local economy, resulting in further induced effects from visitor spending. Economic output is a measure of the total estimated value of the production of goods and services supported by visitor spending, including the direct, indirect, and induced effects.

Table TA 16-19, below, displays the total economic contributions from lake-based recreation occurring in the Glen Canyon National Recreation Area (NRA), which includes Lake Powell, and in the Lake Mead NRA, which includes Lake Mohave. **Table TA 16-20** displays economic contributions associated with Grand Canyon National Park (GCNP).

[7] Direct, indirect, and induced impacts—as used in this context—are economic terms used to describe the impacts from changes in economic activity. For more information on the types of economic activity that are included in each type of impact, please refer to **Section TA 16.2.1**, Methodology.

Table TA 16-19
Summary of Economic Contributions for National Park Service (NPS) Lake-Based Recreation (2023)

NPS Unit	Total Recreational Visits	Visitor Spending (1,000s of 2023$)	Jobs[1]	Labor Income (1,000s of 2023$)[2]	Value Added (1,000s of 2023$)[3]	Economic Output (1,000s of 2023$)[4]	% of Spending from Nonlocals
Glen Canyon NRA	5,206,934	$539,912	6,298	$226,266	$384,281	$670,369	96.3
Lake Mead NRA	5,798,541	$292,463	3,131	$130,744	$219,232	$357,760	88.3

Source: Flyr and Koontz 2024

[1] Jobs measure annualized full- and part-time jobs that are supported by NPS visitor spending.

[2] Labor income includes employee wages, salaries, and payroll benefits, as well as proprietors' incomes, that are supported by NPS visitor spending.

[3] Value added measures the contribution of NPS visitor spending to the GDP of a regional economy. Value added is equal to the difference between the amount an industry sells a product for and the product's production cost.

[4] Economic output is a measure of the total estimated value of the production of goods and services supported by NPS visitor spending. Economic output is the sum of all intermediate sales (business to business) and final demand (sales to consumers and exports).

Table TA 16-20
Summary of Economic Contributions for NPS River-Based Recreation (2023)

NPS Unit	Total Recreational Visits	Visitor Spending (1,000s of 2023$)	Jobs[1]	Labor Income (1,000s of 2023$)[2]	Value Added (1,000s of 2023$)[3]	Economic Output (1,000s of 2023$)[4]	% of Spending from Nonlocals
GCNP	4,733,705	$768,411	10,060	$350,177	$582,513	$1,022,191	98.8

Source: Flyr and Koontz 2024

[1] Jobs measure annualized full- and part-time jobs that are supported by NPS visitor spending.

[2] Labor income includes employee wages, salaries, and payroll benefits, as well as proprietors' incomes, that are supported by NPS visitor spending.

[3] Value added measures the contribution of NPS visitor spending to the GDP of a regional economy. Value added is equal to the difference between the amount an industry sells a product for and the product's production cost.

[4] Economic output is a measure of the total estimated value of the production of goods and services supported by NPS visitor spending. Economic output is the sum of all intermediate sales (business to business) and final demand (sales to consumers and exports).

Total economic output for lake-based recreation was $358 million from Lake Mead NRA and $670 million from Glen Canyon NRA. These amounts reflect total economic output from visitor spending, including spending by local visitors who live in gateway regions and nonlocal visitors who travel to National Park Service (NPS) sites from outside gateway regions. Spending by nonlocal visitors represents an influx of dollars from outside the local economy. In addition, nonlocal visitors typically have higher levels of spending on food, lodging, and other activities on a per-trip basis. Glen Canyon NRA and Lake Mead NRA had 96.3 percent and 88.3 percent of spending from nonlocal visitors, respectively (Flyr and Koontz 2024).

Total economic output for river-based recreation was $1,022 million in GCNP. This amount accounts for total visitor spending, which includes spending by local visitors who live in gateway regions and nonlocal visitors who travel to NPS sites from outside gateway regions. Spending by nonlocal visitors represents an influx of dollars from outside the local economy. In addition, nonlocal visitors typically have higher levels of spending on food, lodging, and other activities on a per-trip basis. GCNP had 98.8 percent of spending from nonlocal visitors (Flyr and Koontz 2024).

River-based recreation is a major component of visitor use and economic activity along the Colorado River corridor. Two activities stand out for their economic and experiential importance: angling in Glen Canyon and whitewater rafting in Grand Canyon. Angling in Glen Canyon below Glen Canyon Dam attracts visitors seeking high-quality trout fishing opportunities, which depend on stable flows and accessible river conditions. These trips generate spending on guide services, lodging, food, and equipment in nearby communities. Similarly, whitewater rafting in Grand Canyon is a nationally important recreational experience, drawing thousands of visitors annually for multiday trips that require specialized guides, equipment, and logistical support. These trips contribute to local economies through outfitter services, transportation, and hospitality sectors. For additional details on recreation and levels of use, see **TA 14**, Recreation.

Beyond direct spending, these activities provide considerable nonmarket recreational benefits, often expressed as consumer surplus. Consumer surplus represents the additional benefit participants receive beyond their actual costs, reflecting the unique quality and scarcity of these experiences. Flow conditions influence both angling success and rafting trip quality, making river operations an important factor in sustaining these values.

Recreational visits to Glen Canyon NRA and Lake Mead NRA correspond with a wide array of job sectors within local (predominately small town and rural) economies. **Table TA 16-21** shows the key sectors supported through recreation in Glen Canyon NRA and Lake Mead NRA. In 2023, Glen Canyon NRA recreation supported 6,300 jobs, including 1,467 indirect and induced jobs. In 2023, Lake Mead NRA recreation supported 3,131 total jobs, including 872 indirect and induced jobs (Flyr and Koontz 2024).

Table TA 16-21
Jobs by Sector Supported by Economic Contributions from NPS Lake-Based Recreation (2023)

Jobs	Glen Canyon NRA	Lake Mead NRA
Direct jobs by sector		
Camping	130	122
Gas	108	79
Groceries	145	155
Hotels	2,112	613
Recreational industries[1]	851	261
Restaurants	1,009	792
Retail	257	185
Transportation	221	52
Indirect and induced jobs	1,467	872
Total jobs	6,300	3,131

Source: Flyr and Koontz 2024

[1]Recreational industry jobs include those associated with expenditures on equipment rentals, amusement activities and guide/tour fees.

Table TA 16-22 shows that GCNP recreation supported 10,064 jobs, including 2,316 indirect and induced jobs, in 2023. In addition to the direct economic impact from gross revenues on GCNP and the NPS, it is estimated that the regional economic impact of commercial river trips supports hundreds of additional jobs and generates millions in additional revenue throughout the mostly rural communities and small businesses of northern Arizona and southern Utah each season.

Table TA 16-22
Jobs by Sector Supported by Economic Contributions from NPS River-Based Recreation (2023)

Jobs	GCNP
Direct jobs by sector	
Camping	156
Gas	99
Groceries	134
Hotels	2,630
Recreational industries	2,032
Restaurants	1,631
Retail	460
Transportation	606
Indirect and induced jobs	2,316
Total jobs	**10,064**

Source: Flyr and Koontz 2024

[1]Recreational industry jobs include those associated with expenditures on equipment rentals, amusement activities and guide/tour fees.

In addition to general recreation sector contributions, visitor use supports concessionaires, including those associated with water-based recreation, such as commercial river trips. In GCNP, commercial river trips hosted 17,313 passengers in 2023, which was a decrease from 19,990 passengers in 2022 and 20,749 passengers in 2021. From these river trips, river concessionaires contributed $63.6 million in 2023 in gross revenue, representing 29 percent of the total concessionaire revenue at GCNP, which amounted to $220 million that year. Gross revenue from river concessionaires remained relatively consistent from 2021 to 2023, with a small decrease from $66.4 million in 2021 to $61.8 million in 2022, followed by a small increase to $63.6 million in 2023 (2021 and 2022 values adjusted for inflation to 2023$). River concessioner franchise fees paid to the NPS in 2023 totaled $6.25 million, 80 percent of which stays at GCNP.[8] It should be noted that concessionaires include those operated by tribes, particularly at the Antelope Valley Marina, which is on the Navajo Nation's reservation.

National wildlife refuges (NWRs) also support economic contributions through expenditures from recreational visitors, such as expenditures for entrance fees, lodging near the refuges, and purchases from local businesses for items to pursue the visitors' recreational experience, including, but not limited to, food and recreational gear. This spending supports economic activity throughout the local economy (Caudill and Carver 2019). Three refuges receive Colorado River water: Imperial NWR, Cibola NWR, and Havasu NWR. Based on 2017 data, the most recent publicly available information, Imperial NWR, located in Arizona and California, had 274,159 visits and supported 100 jobs and $11.1 million in total economic output (see **Table TA 16-23**). Equivalent data are not available for Cibola and Havasu NWRs.

Table TA 16-23
Economic Contributions from NWRs (2017)[1]

NWR	Total Recreational Visits	Total Economic Output ($1,000)	Total Employment Income ($1,000)	Total Jobs
Imperial NWR (Arizona and California)	274,159	$11,069.8	$3,228.6	100

Source: Caudill and Carver 2019

[1] The data shown are presented for 2017, which is the most recent publicly available data.

TA 16.1.4 Demographics

Population is a driver of demand for consumptive water use. Populations throughout much of the western U.S. have followed trends of increasing populations over the past decade. Details of population trends and forecasts are provided in **TA 17**, Population and Land Use**.**

In addition to overall population trends, racial and ethnic composition can play a role in determining social and cultural groups with potential for impacts from changes to river operations. **Table TA 16-24**, Study Area Demographics (2023), shows the racial and Hispanic composition for the study area counties, as well as the composition for Arizona, California, Nevada, and Utah.

[8] Laurie Dyer, NPS supervisory concessions management specialist in the Commercial Services Division at GCNP, personal communication provided on September 27, 2024.

Table TA 16-24
Study Area Demographics (2023)

Geographic Area	Total Population	White (%)	Black or African American (%)	American Indian and Alaska Native (%)	Asian (%)	Native Hawaiian and Other Pacific Islander (%)	Some Other Race (%)	Two or More Races (%)	Hispanic or Latino (of Any Race) (%)	White Alone, not Hispanic or Latino (%)
State Data										
Arizona	7,268,175	63.20	4.60	4.10	3.40	0.20	8.20	16.2	31.00	53.40
California	39,242,785	44.00	5.50	1.10	15.30	0.40	17.40	16.30	39.80	34.60
Nevada	3,141,000	53.20	9.40	1.30	8.70	0.70	11.80	14.80	29.20	46.00
Utah	3,331,187	80.70	1.10	1.00	2.40	0.90	5.60	8.30	15.40	75.70
County Data										
Apache County, Arizona	65,680	20.20	1.00	72.10	0.60	0.10	1.30	4.70	6.20	18.60
Coconino County, Arizona	144,643	57.00	1.50	25.20	1.80	0.10	5.40	8.90	15.20	52.50
Gila County, Arizona	53,610	67.70	0.60	13.20	0.80	0.10	4.50	13.10	17.80	62.00
Graham County, Arizona	38,860	66.20	1.30	11.40	0.60	0.70	3.90	15.80	30.30	53.10
La Paz County, Arizona	16,605	61.30	0.40	14.20	1.10	0.00	6.90	16.00	25.50	57.80
Maricopa County, Arizona	4,491,987	63.00	5.80	1.90	4.40	0.20	8.40	16.40	30.90	53.40
Mohave County, Arizona	217,420	81.50	1.20	1.60	1.10	0.20	4.90	9.50	16.70	75.60
Navajo County, Arizona	107,744	45.40	1.20	43.10	0.40	0.20	3.30	6.50	10.60	42.40
Pima County, Arizona	1,049,947	63.20	3.60	3.10	3.00	0.20	9.90	17.00	36.10	51.20
Pinal County, Arizona	449,219	66.00	5.00	4.70	1.70	0.40	8.30	13.90	29.30	55.90
Yavapai County, Arizona	241,656	82.70	0.60	1.50	1.10	0.10	4.40	9.70	15.00	78.30
Yuma County, Arizona	207,685	48.40	1.70	1.40	1.10	0.10	13.20	34.10	64.40	29.60
Imperial County, California	179,319	30.40	2.50	1.60	1.50	0.00	37.80	26.20	85.60	9.40
Los Angeles County, California	9,848,406	35.40	7.80	1.30	15.00	0.20	23.60	16.70	48.30	25.20
Orange County, California	3,164,063	46.40	1.60	0.80	21.90	0.30	14.10	14.90	34.10	37.70
Riverside County, California	2,449,909	42.20	6.50	1.20	7.00	0.30	24.30	18.50	50.60	32.00

Geographic Area	Total Population	White (%)	Black or African American (%)	American Indian and Alaska Native (%)	Asian (%)	Native Hawaiian and Other Pacific Islander (%)	Some Other Race (%)	Two or More Races (%)	Hispanic or Latino (of Any Race) (%)	White Alone, not Hispanic or Latino (%)
San Bernardino County, California	2,187,816	39.10	8.00	1.30	8.10	0.30	24.50	18.60	54.60	25.60
San Diego County, California	3,282,782	53.00	4.70	0.90	12.20	0.40	10.60	18.10	34.30	43.20
Clark County, Nevada	2,293,764	47.10	12.10	1.10	10.50	0.80	12.90	15.50	31.40	39.40
Garfield County, Utah	5,170	94.70	0.10	2.10	0.00	0.50	0.90	1.70	7.00	89.30
Kane County, Utah	7,996	90.80	0.20	2.20	0.10	0.10	2.40	4.20	4.80	88.70
San Juan County, Utah	14,466	46.70	0.10	45.90	0.50	0.40	3.00	3.30	5.60	44.90

Source: U.S. Census Bureau 2023b

Several counties in the study area had American Indian and Alaska Native populations that were higher than the respective state level. In Arizona, Apache (72.1 percent), Coconino (25.2), Gila (13.2 percent), Graham (11.4 percent), La Paz (14.2 percent), and Navajo (43.1 percent) Counties had American Indian and Alaska Native populations far exceeding the state population of 4.1 percent.

According to 2023 census data, 13 of the study area counties had Hispanic or Latino populations exceeding 25 percent of the total population. In Arizona, the Hispanic or Latino population exceeds 25 percent in Graham (30.3 percent), La Paz (25.5 percent), Maricopa (30.9 percent), Pima (36.1 percent), Pinal (29.3 percent), and Yuma (64.4 percent) Counties. In California, the Hispanic or Latino population exceeded 31 percent in Imperial (85.6 percent), Los Angeles (48.3 percent), Orange (34.1 percent), Riverside (50.6 percent), San Bernardino (54.6 percent), and San Diego (34.3 percent) Counties. Clark County, Nevada, had a Hispanic or Latino population of 31.4 percent. In contrast, in the three Utah study area counties, the Hispanic or Latino population comprised between 4.8 percent and 7.0 percent of the total population.

TA 16.1.5 Social and Nonmarket Values

Nonmarket values refer to resource benefits that are not captured in market transactions or traditional economic measures. Along the Colorado River, these values include the enjoyment of natural scenery, opportunities for recreation and solitude, preservation of landscapes, and the symbolic and ecological importance of the river itself. Such values are important for understanding how river operations affect people's experiences, sense of place, and well-being, even when no direct economic exchange is involved.

Place-based communities along the Colorado River corridor derive nonmarket values from their proximity to the river and its resources. Gateway communities such as Page, Arizona; Boulder City, Nevada; Bullhead City, Arizona; and Lake Havasu City, Arizona, benefit from river-related recreation and tourism and identify with the surrounding landscape as part of their community character. Agricultural communities in counties in Arizona and California are closely tied to irrigated farmland supported by Colorado River water, and their identity is shaped in part by this long-standing relationship between land and water. Residents of these communities often emphasize quality of life, access to outdoor spaces, and continuity of traditional uses as nonmarket dimensions of the river.

In addition to supporting place-based communities, the river also supports nonmarket values for non-place-based communities. These include recreationists and visitors from across the U.S. who seek rafting, boating, angling, or other experiences on the river, as well as individuals who may never visit but who value the river for its ecological health, scenic integrity, or symbolic importance as a national resource. Conservation organizations and advocacy groups also emphasize the preservation of nonmarket values such as wilderness character and ecosystem health.

The expression of these values varies, but they generally encompass cultural identity, recreational quality, aesthetics, and existence values. For local communities, this may involve community identity or reliance on a healthy river system for recreational opportunities. For nonlocal stakeholders, it often reflects support for maintaining the river's ecological and scenic qualities. These values are not

measured through market activity but are nevertheless a critical part of how people interact with and assign meaning to the Colorado River.

Together, these social and nonmarket values establish a baseline for evaluating the social and cultural environment in the Colorado River Basin (Basin). They highlight that the river provides more than economic contributions; the river supports community identity, recreational experiences, and environmental quality that extend beyond direct market measures. These values provide important context for assessing potential changes under the post-2026 operational alternatives.

TA 16.2 Environmental Consequences

TA 16.2.1 Methodology

The following subsection outlines the methodology, impact analysis area, and assumptions used in the analysis of impacts on economic and social conditions from changes in agriculture and recreation as well as the analysis of impacts on ecosystem services and nonmarket values. For an analysis of impacts on hydropower, including impacts on energy generation, electricity rates, and market value, refer to **TA 15**, Dams and Electrical Power Resources. For an analysis of impacts on social and economic conditions from changes in domestic water, including impacts on municipal and industrial water users, refer to **TA 17**, Population and Land Use.

Agriculture

The purpose of the agricultural impact assessment is to estimate the change in economic conditions from changes in agricultural production from a reduction of irrigation water. The change in the value of agricultural production is directly related to the acres of cropland assumed to be fallowed and the estimated forgone revenue per acre of the fallowed crop. In addition to revenue loss from agricultural products, agricultural jobs and wages would potentially be lost. To analyze the impacts on economic conditions from these changes in agriculture, the U.S. Bureau of Reclamation (Reclamation) used a similar agricultural modeling framework that was applied in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (2007 Final EIS; Reclamation 2007) and the Near-term Colorado River Operations Final Supplemental Environmental Impact Statement (2024 Final SEIS; Reclamation 2024), with some changes and updates as discussed below.

As described in **TA 4**, Water Deliveries, Reclamation used the Colorado River Simulation System to analyze water deliveries across the alternatives. Modeling details for each alternative are described in **Chapter 2**, Description of Alternatives and **Appendix S**, Additional Description of Alternatives. Additionally, as described in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, Reclamation used Shortage Allocation Models and Alternative Distribution Models in addition to the Colorado River Simulation System to analyze the potential impacts of the alternatives on individual agricultural water users within each Lower Division State under different shortage scenarios. Based on the Shortage Allocation and Alternative Distribution Models, Reclamation estimated the change in agricultural revenue for each priority group by county and state in the analysis area where the individual agricultural and tribal agricultural water users were being

affected from water shortages at a variety of shortage levels across each alternative and comparative baseline.

Irrigated crops in the analysis area that were analyzed include field crops, vegetables, and fruit and nut trees and vines, separated out into agricultural crop group types, where at least approximately one percent of a county's harvested acres come from the crop group (USDA 2024; Reclamation 2016; Imperial County 2019, 2020, 2021, 2022, 2023; Riverside County 2020, 2021, 2022, 2023; San Bernardino County 2019, 2020, 2021, 2022, 2023). The methodology for estimating which crops would be fallowed first is the same as that used in the 2007 Final EIS and the 2024 Final SEIS and is based on the crops' water use and the farmer's ability to cover the variable cost of production of a given crop, which is based on the profitability of the crop (Dale and Dixon 1998; Frisvold et al. 2013). The analysis assumes that the least profitable crop would be fallowed first, analyzed for each priority group in each county separately. Crops would continue to be fallowed in the order of least profitable crop, until the full volume of water shortage is offset.

Calculation of crop profitability per acre-foot of water followed the method outlined in Appendix H of the 2007 Final EIS, which used the difference between revenue and the variable costs per acre of land required to grow a given crop. Based on the order of fallowing and the shortages analyzed across the alternatives, the following eight crop group types were analyzed: alfalfa, cotton, cruciferous vegetables, field grains, fruit and tree nuts and vines, other hay and haylage, small grains, and small vegetables.

To determine how much a farmer would be willing to pay for water before a choice is made to fallow a crop, the cost of irrigation for growing each crop was added back to the calculated revenue minus the variable production cost. To account for each crop's required amount of water (different for each crop), the estimated return plus the irrigation cost was divided by the amount of water per acre needed to grow that crop (USDA 2024; Reclamation 2016; University of Arizona 1999, 2001, 2023, 2025; University of Nevada 2004, 2007, 2010, 2012, 2022; University of California 1956, 1962, 1963, 1964, 1965, 1967, 1972, 1973, 1974, 1975, 1977, 1978, 1979, 1984, 1988, 1989, 1992, 1995, 1996, 1997, 1998, 2000, 2002, 2004, 2011). Based on this method, the order in which crops would be fallowed varied across the counties in the study area.

County-level operational cost data for each crop, including the difference in irrigation cost, are not updated frequently. To capture the difference in the irrigation cost for each crop in different counties in Arizona, California, and Nevada, variable costs-of-production estimates were based on historical crop and livestock budgets developed by the University of Arizona, University of California Davis, and University of Nevada Reno, respectively, for a range of years, depending on the type of crop and county for which it was developed (University of Arizona 1999, 2001, 2023, 2025; University of Nevada 2004, 2007, 2010, 2012, 2022; University of California 1956, 1962, 1963, 1964, 1965, 1967, 1972, 1973, 1974, 1975, 1977, 1978, 1979, 1984, 1988, 1989, 1992, 1995, 1996, 1997, 1998, 2000, 2002, 2004, 2011; USDA ERS 2025). For operational cost and irrigation cost data that were not available for specific crops grown in the county, estimated data were used based on data from nearby counties or from nearby states or regions for the same or similar crops. All dollar values were converted to 2022 dollars. The purpose of using the cost estimates was only to

determine the order in which crops would be fallowed; the estimates are not considered an accurate measure of the current cost and return estimates.

Forgone agricultural revenue from fallowed crops was estimated by multiplying the county-level revenue per acre by the number of acres reduced (or fallowed) for each crop. The county-level revenue was calculated based on the most recent available data on yields and prices. The number of acres reduced for each crop was modeled based on the order in which crops would be fallowed, the level of shortages and available water for each priority group by county and state, and the most recent available data on acres harvested (USDA NASS 2024; Reclamation 2016; Imperial County 2019, 2020, 2021, 2022, 2023; Riverside County 2020, 2021, 2022, 2023; San Bernardino County 2019, 2020, 2021, 2022, 2023). For data that were not available for specific crops grown in the county, estimated data were used based on statewide averages, data from nearby counties, or averages from nearby states or regions for the same or similar crops.

Reclamation acknowledges that it is difficult to project exactly how individual farmers, irrigation districts, or each Lower Division State may mitigate potential future agricultural impacts from shortages. For example, farmers may use groundwater and other surface water resources to mitigate impacts from allocated shortages; however, the amount of groundwater that the farmers would use to replace the surface water depends on many factors, such as the amount of groundwater available, local and state restrictions on groundwater pumping, and the cost of pumping. Therefore, similar to the assumption made in the 2007 Final EIS and the 2024 Final SEIS, the quantitative projected change in agricultural production did not include the use of groundwater as a replacement water source; however, the use of groundwater to replace the estimated water shortage is discussed qualitatively.

As in the 2007 Final EIS and the 2024 Final SEIS, impacts on economic conditions, such as jobs and income, from changes in agricultural production were analyzed using the IMPLAN input-output economic model. IMPLAN is a regional economic model that describes the flow of money, goods, and services from producers to intermediate and final consumers using a series of economic multipliers. The IMPLAN model provides annual average estimates of how a direct change in economic spending (such as through reduced agricultural revenues) would ripple through the broader economy and other industries. These ripple or multiplier effects include (1) indirect impacts resulting from changes in economic activity in industries that sell inputs to the industries that may be directly affected (for example, changes in supply purchases made by agricultural producers or farmers) and (2) induced impacts resulting from changes in household spending as households adjust their spending in response to changes in labor income supported by industries affected by management actions (for example, changes in purchases at local stores for personal groceries).

This analysis used IMPLAN Cloud and data from IMPLAN's 2023 data release (the most recent period of data available on the IMPLAN Cloud platform at the time of analysis; IMPLAN 2025). Prior to running the model, cost data were converted to a consistent dollar year (2025). Unless stated otherwise, monetary values are reported in the year 2025 dollars.

The modeled shortage volumes, based on the Shortage Allocation and Alternative Distribution Models, are presented in terms of consumptive use shortage relative to the consumptive use (or

modeled equivalent) entitlement, in order to allow for comparison across the alternatives and shortage distribution methods. This is a change to volumetric shortage modeling from the 2007 Final EIS and the 2024 Final SEIS, which modeled shortages relative to future demand schedule or recent history of use, respectively. However, the quantitative agricultural economic analysis in this Final Environmental Impact Statement (EIS) captures the impacts that occur from immediate reductions in available water; it does not capture impacts on future water consumption expansion and development opportunities for irrigation entitlement holders with current consumptive use that is less than their entitlement. Many uncertain factors impact future consumption, so impacts from shortages on water consumption expansion opportunities for irrigation entitlement holders with current consumptive use that is less than their entitlement will be discussed qualitatively.

Impact Analysis Area

Potential changes in economic contributions and social conditions from agricultural production within the analysis area due to estimated shortages were quantitatively assessed for the counties expected to experience impacts; these are Apache, Coconino, Gila, Graham, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, Yavapai, and Yuma Counties in Arizona; Imperial, Riverside, and San Bernardino Counties in California; and Clark County in Nevada.

Quantitative impacts were analyzed at the county level and presented at the state level, for comparison purposes.

Assumptions

For the purposes of this analysis, Reclamation included the assumptions listed below. Any future changes in these assumptions would change the impacts on economic contributions and social conditions associated with agriculture. The extent to which impacts on economic contributions and social conditions change due to changes in assumptions depends on many factors and future conditions that Reclamation cannot predict with sufficient certainty to quantify in this EIS; however, where possible and as stated below, a qualitative discussion on the impacts of changes in the assumptions is provided in the impacts analysis.

- All dollar values in the impacts analysis are reported in 2025 dollars, unless otherwise noted.
- Farmers would fallow irrigated crops in response to water shortages or an increased cost of irrigation. Farmers would fallow the land rather than switch from one crop to an alternative, more profitable or less water-intensive crop due to investments and institutional knowledge that have been made in plants, supply chains and relationships, and/or machinery that create barriers for changing crops. Reclamation understands there could be farmers who are able to switch crops rather than fallow; however, for the purpose of this analysis, this assumption provides a bound to the analysis, and any changes in this assumption would likely result in less impacts than discussed below.
- As discussed above, the analysis assumes the least profitable crop would be fallowed first, analyzed for each county separately, and crops were assumed to have constant profitability per acre of land and per acre-foot of water. Reclamation understands that often farmers will plant lower-valued crops on an annual or seasonal rotation to support or prepare the soil for higher-valued crops; additionally, Reclamation acknowledges that markets fluctuate and that reduced availability or production of crops could change the prices, which could change

crop profitability and farmers' decisions of which crop to plant or fallow. Reclamation cannot predict with sufficient certainty the crop rotation patterns that farmers may choose or how markets will react to changes in crop production. The analysis assumption that crops would be fallowed in order of profitability and that profitability is held constant provides an estimated benchmark to allow for a comparison of impacts across alternatives.

- Changes in irrigated crop acreages would result from changes in water deliveries from the Colorado River sources; they do not involve changes to allocations or to irrigation water from groundwater or other surface water sources. Due to the uncertainties associated with the quantity of Colorado River irrigation water that would switch to groundwater, as well as other market factors that affect groundwater availability and cost, it is not possible to quantify the impacts on social and economic conditions from switching to groundwater; however, the use of groundwater to replace the estimated water shortage is discussed qualitatively.
- Estimated shortages in the agricultural sector are based on the Shortage Allocation and Alternative Distribution Models (**Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation). Shortages to individual entitlement holders are measured in terms of consumptive use for a common basis of comparison with state apportionments and volumes of total shortage. Impacts on future opportunities to expand water use due to shortages for irrigation entitlement holders who currently use less than their entitlement are discussed qualitatively.
- The analysis does not assume that compensated conservation programs or other incentives for fallowing land are employed. This assumption provides a bound to the analysis; however, Reclamation acknowledges that conservation programs and adaptation measures could be implemented in the future and would lessen the impacts discussed below.
- In most cases, the contractor, subcontractor, or entitlement holder of an allocation is shown as the entity bearing shortage. In some cases, water allocated to an entitlement holder (for example, a tribal CAP contractor) may lease its allocation to other users (for example, to a non-Indian municipality). The Shortage Allocation and Alternative Distribution Models do not attempt to replicate those arrangements, and they only provide approximate estimates at the level of the entitlement holder, contractor, or subcontractor. The entitlement holder, contractor, or subcontractor to the leasing arrangements would have specific decisions to make during Shortage Conditions to administer those arrangements; Reclamation cannot predict these decisions with sufficient certainty to analyze in this EIS.
- If an entitlement holder leases water allocation to another type of user (for example, if an irrigation entitlement holder leases water to a tribal or non-tribal municipality or if a tribal or non-tribal CAP contractor leases to an agricultural water user), then a shortage in water deliveries would likely result in a financial impact on the entitlement holder. This would also result in an impact from a reduction in water availability on the end users; these impacts would be similar to those impacts discussed below for agricultural end users or as discussed in **TA 17**, Population and Land Use, for municipal and industrial end users.

Impact Indicators

- Change in acres of fallowed cropland
- Change in production value or revenue associated with fallowed cropland
- Change in jobs and income associated with agriculture
- Change in nonmarket values and social conditions associated with changes in agriculture

Recreation

The recreational economic impact analysis evaluates how operational changes under the alternatives may influence visitor spending and related economic activity in the Colorado River corridor (see **TA 14**, Recreation, for discussion of impacts on recreation). For an analysis of impacts of reservoir elevation on hydropower, including impacts on energy generation, refer to **TA 15**, Dams and Electrical Power Resources. For lake-based recreational economic contributions, the approach integrates estimates of baseline visitor use with spending profiles and applies a regional economic modeling framework, primarily IMPLAN, to estimate total economic contributions. Visitor use levels are derived from data reported by the NPS Public Use Statistics Office and Reclamation visitor counts, with visits categorized by activity type (for example, day use, overnight camping, and boating). Total visitor counts were divided by the average party-size data from the NPS to estimate the number of visiting parties for analysis; this is because the spending profile data are by party.

Visitors are further classified by type to reflect differences in recreational behavior and spending. Categories include local versus nonlocal visitors, day trips versus overnight stays, and distinctions among camping and lodging in nearby communities or other site-specific recreational activities. For each visit type, spending profiles are assigned based on available NPS and regional survey data. Profiles capture expenditures across categories such as lodging, food and beverages, transportation, recreational equipment and guide services, entrance and activity fees, and miscellaneous retail purchases.

Visitor spending estimates are then aggregated and input into the IMPLAN regional input-output model to estimate economic impacts. The model distinguishes among direct effects (visitor purchases in the local economy), indirect effects (business-to-business transactions, such as hotel purchases of supplies), and induced effects (household spending supported by recreation-related employment). Results are reported as total visitor spending, jobs supported, labor income, value added (contribution to gross regional product), and total sales. Impacts on direct, indirect, and induced economic contributions by alternative are discussed qualitatively.

A baseline assessment of economic contributions from river-based general recreation using the input-output analysis is included; it uses the same methodology as described above for lake-based recreation.

For the action alternatives, potential changes to recreation's contributions are discussed qualitatively, based on the Decision Making under Deep Uncertainty (DMDU) modeling output and conclusions related to Lake Powell and Lake Mead access to recreation and river-based recreation, as determined by river flow levels and fluctuations, as discussed in **TA 14**, Recreation.

In addition, for boating and angling, the socioeconomic analysis includes changes in the net economic value for a subset of activities, specifically angling in Glen Canyon and whitewater rafting in Grand Canyon. This approach follows the methods used in the Glen Canyon Dam Long-Term Experimental and Management Plan Final Supplemental Environmental Impact Statement (SEIS), where past survey research (Bishop et al. 1987; Neher et al. 2017) informed models to project the change in net economic value under different river flow scenarios. These models link willingness-to-pay estimates for anglers and boaters to hydrologic conditions, providing a measure of recreational benefits that extends beyond market spending (Bair 2026).

Reclamation used similar methods for the analysis of potential impacts on recreation as were used in the 2007 Final EIS and 2024 Final SEIS to assess the effects on recreational value associated with whitewater boating and angling. This analysis also incorporates additional DMDU concepts, specifically robustness heat maps and conditional box plots, developed to provide an indicator of an alternative's performance across many possible hydrologic futures. Refer to **Section TA 3.2.6** in **TA 3**, Hydrologic Resources, for an overview of interpreting the DMDU robustness heat maps and conditional box plots.

Impacts on river-based concessionaires are also assessed qualitatively using existing NPS and outfitters' data and informed by modeled flow thresholds from **TA 14**, Recreation.

For recreation at Imperial NWR and Bill Williams River NWR, baseline economic contribution data are drawn from U.S. Fish and Wildlife Service visitor spending reports, with impacts discussed qualitatively due to limited modeling inputs.

Impact Analysis Area

The analysis area is consistent with the general socioeconomic study area defined in **Chapter 3**. This includes major recreational hubs, gateway communities, and rural areas where economies rely heavily on river- and reservoir-based recreation. Specifically, the recreation impact analysis area encompasses three primary NPS units: Lake Mead NRA, Glen Canyon NRA, and GCNP.

Gateway counties associated with these areas include the following:

- Lake Mead NRA—Clark County and Lincoln County (Nevada); Mohave County (Arizona)
- Glen Canyon NRA (Lake Powell)—Coconino County (Arizona); Garfield, Kane, San Juan, and Wayne Counties (Utah)
- GCNP—Coconino, Mohave, Navajo, and Yavapai Counties (Arizona)

These counties represent the primary economic regions where visitor spending and recreation-related employment occur.

Assumptions

For the purposes of this analysis, Reclamation included the assumptions listed below. Any future changes in these assumptions would change the impacts on economic contributions associated with recreation. The extent to which impacts on economic contributions and social conditions change

due to changes in assumptions depends on many factors and future conditions that Reclamation cannot predict with sufficient certainty to analyze in this EIS.

- All dollar values in the impacts analysis are reported in 2025 dollars, unless otherwise noted.
- Lake-based recreational spending per visitor trip is based on the most recent NPS Visitor Spending Profiles.
- IMPLAN results represent regional effects, including direct, indirect, and induced economic activity associated with lake-based recreation.
- Recreational spending per trip for anglers and whitewater rafting (adjusted for inflation) would follow results from willingness-to-pay surveys (Gaston et al. 2015) with variation based on river flows.

Impact Indicators

- Changes in direct recreational visitor spending across the affected NPS units and recreation sites
- Changes in regional employment, labor income, value added, and total economic output from lake-based recreation-related activities
- Impacts on the recreational value associated with river-based boating and angling
- Effects on commercial outfitters, concessionaires, and permittees, especially in areas dependent on rafting, boating, and guided recreation

Ecosystem Services and Nonmarket Values

The discussion of ecosystem services and nonmarket values is provided in a qualitative format based on existing literature.

Impact Analysis Area

- The analysis area for social and nonmarket values is the Colorado River corridor from Lake Powell to the Southerly International Boundary, consistent with the overall socioeconomic study area.
- Consideration is focused on but not limited to geographic boundaries; this is because non-place-based communities also hold nonmarket values. Therefore, the area includes both local communities along the river and the broader public for whom the river holds symbolic, ecological, or recreational importance.

Assumptions

For the purposes of this analysis, Reclamation assumed the following:

- Nonmarket values are not directly quantifiable through market-based indicators; instead, they can be described qualitatively based on existing studies, stakeholder input, and related resource analyses.
- Changes in nonmarket values are assumed to be closely linked to conditions evaluated in the other technical appendixes, such as those for recreation, population and land use, cultural resources, and visual resources.

- Changing hydrology may influence how these values are perceived, particularly where access, scenic character, or ecological conditions are affected.

Impact Indicators

- Changes in the availability or quality of recreational opportunities not captured by direct spending
- Changes in the river's existence and symbolic values due to shifts in the scenic character or ecological conditions

TA 16.2.2 Issue 1: How would the anticipated water shortages affect the economic contributions and social conditions from agriculture?

Under all alternatives and the Continued Current Strategies (CCS) Comparative Baseline, anticipated shortages would result in increases in acres of fallowed cropland and agricultural production losses, and the modeled agricultural production loss would result in impacts on the associated jobs, income, and total economic output. However, there are regional differences as well as differences in magnitude of impacts across the alternatives and the CCS Comparative Baseline, as discussed below.

As shown in figures below (**Figure TA 16-1** through **Figure TA 16-10**), there are two sets of model results for the Representative Preferred Alternative: those for the first 2 years (2027-2028) and those for beyond the first 2 years (2029-2060). As described in **Chapter 2**, under the Representative Preferred Alternative in the first 2 years (2027 – 2028), the shortages are distributed via LB priority up to 1.5 million acre-feet (maf) and shortage volumes above 1.5 maf up to 3.6 maf are distributed using the priority system, and under the Representative Preferred (2029-2060) Alternative, all volumes of shortages are distributed via the priority system. Refer to **Appendix C**, Table C-27 and Table C-26 for shortage impacts for each irrigation and tribal entitlement holder, respectively, under the LB Priority distribution (up to 1.5 maf shortage). The 2027 and 2028 operating guidelines modeling is compared to the Representative Preferred Alternative in **Appendix T,** Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028. Expected impacts from beyond 2028 under the Preferred Alternative may be different from what is shown in the figures below for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**.

Figure TA 16-1 presents the estimated number of agriculture acres fallowed for each alternative and the CCS Comparative Baseline, across a range of shortage volumes—0.6 maf to 4.0 maf—for non-tribal and tribal irrigation entitlement holders in Arizona, California, and Nevada (see **Figure TA 16-2** and the discussion below for impacts broken out by priority group, and shortages by individual entitlement holder are shown in **Appendix C**). The shading highlights the magnitude of fallowed croplands across the alternatives and the CCS Comparative Baseline and shortage levels for each state and entitlement holder group, with the darker shaded numbers representing larger magnitudes of fallowed croplands. Across the alternatives and the CCS Comparative Baseline, the greatest impacts on fallowed lands occur in Arizona on non-tribal and tribal agriculture entitlement holders as well as California non-tribal agriculture entitlement holders. On average, for non-tribal agriculture entitlement holders in Arizona and California with shortages less than or equal to 3.0 maf, the greatest impacts on fallowed lands occurs under the Enhanced Coordination or Supply Driven

(Lower Basin [LB] Pro Rata approach) Alternatives, compared with the CCS Comparative Baseline and the other alternatives, including the Representative Preferred Alternative. During shortages greater than 3.0 maf, for non-tribal agriculture entitlement holders in Arizona, the greatest impacts on fallowed lands occur under the Representative Preferred (2029-2060) and Maximum Operational Flexibility Alternatives, due to the larger maximum shortages allowed under these alternative. However, for non-tribal agriculture entitlement holders in California, the greatest impacts on fallowed lands, during shortages greater than 3.0 maf, occur under the Enhanced Coordination Alternative, due to the pro rata-based shortage distribution method. When comparing impacts due to maximum levels of shortages across all alternatives and the CCS Comparative Baseline, for Arizona non-tribal entitlement holders, the Maximum Operational Flexibility Alternative would result in the greatest level of impacts on fallowed lands (with an increase of about 103,000 acres of fallowed lands) during a maximum shortage of 4.0 maf, and for California non-tribal entitlement holders, the Enhanced Coordination Alternative would result in the highest level of impacts on fallowed lands (with an increase of about 283,000 acres of fallowed lands) during a maximum shortage of 3.0 maf. When the shortage is 0.6 maf, the smallest impacts on fallowed lands occurs under the Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred (2027-2028) Alternatives for Arizona non-tribal entitlement holders, and there would be no impacts on fallowed lands for California non-tribal entitlement holders under the CCS Comparative Baseline and the No Action, Representative Preferred, Basic Coordination, Maximum Operational Flexibility, and Supply Driven (LB Priority approach) Alternatives. During maximum levels of shortage, the lowest impacts on fallowed lands would occur under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, with an increase in total fallowed land across Arizona and California non-tribal entitlement holders of about 6,000 acres (with a shortage of 1.0 maf) under the CCS Comparative Baseline, 1,000 acres (with a shortage of 0.6 maf) under the No Action Alternative, and 7,000 acres (with a shortage of 1.5 maf) under the Basic Coordination Alternative.

On average, across all Arizona tribal entitlement holders combined, when the shortage is 0.6 maf, the largest impacts on fallowed lands occurs under the Supply Driven Alternative (LB Pro Rata approach) and the smallest impacts on fallowed lands occurs under the Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred (2027-2028) Alternatives. For shortages greater than 0.6 maf but not more than 1.5 maf, impacts on fallowed lands would be largest under the Basic Coordination and Representative Preferred (2029-2060) Alternatives and smallest under the No Action Alternative, because the maximum shortage for this alternative is 0.6 maf. For shortages greater than 1.5 maf, impacts on fallowed lands would be greatest under the Representative Preferred (2029-2060) and Maximum Operational Flexibility Alternatives, with annual impacts as large as an increase in fallowed lands of about 67,000 acres (occurring during a shortage of 3.6 maf under the Representative Preferred (2029-2060) Alternative) and 68,000 acres (occurring during a shortage of 4.0 maf under the Maximum Operational Flexibility Alternative). The maximum level of impacts on fallowed lands due to shortages for Arizona tribal entitlement holders were the lowest under the No Action Alternative (with about 12,000 acres fallowed under a shortage of 0.6 maf; see **Figure TA 16-1**). However, as discussed below, these impacts vary across priority groups.

Figure TA 16-1
Annual Acres of Fallowed Cropland in the Analysis Area by Alternative and Shortage Level, in Thousand Acre-feet (kaf)

State, Water Entitlement Holders	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture	CCS Comparative Baseline[1]	1,695	2,747								
	No Action Alternative	1,222									
	Basic Coordination Alternative[2]	1,222	3,882	7,322							
	Enhanced Coordination Alternative	9,068	15,076	22,743	27,808	32,368	34,643	40,346	62,044		
	Maximum Operational Flexibility Alternative	464	2,007	3,764	5,591	7,063	8,074	9,854	29,489	75,029	103,065
	Supply Driven (LB Priority Approach) Alternative	464	2,007	3,764	5,591	7,063	8,074				
	Supply Driven (LB Pro Rata Approach) Alternative	17,875	26,374	44,351	52,435	57,825	60,520				
	Representative Preferred (2027-2028) Alternative[3]	464	2,007	3,764	5,591	7,063	8,074	9,854	29,489	75,029	
	Representative Preferred (2029-2060) Alternative[4]	1,222	3,882	7,322	10,108	10,275	12,291	19,115	51,279	91,032	
California, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0	3,305								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	71,341	105,664	148,567	174,309	191,471	200,052	217,213	283,363		
	Maximum Operational Flexibility Alternative	0	0	12,276	12,276	12,276	12,276	12,276	114,402	170,047	226,560
	Supply Driven (LB Priority Approach) Alternative	0	0	12,276	12,276	12,276	12,276				
	Supply Driven (LB Pro Rata Approach) Alternative	39,213	65,020	97,280	125,152	143,734	153,024				
	Representative Preferred (2027-2028) Alternative[3]	0	0	12,276	12,276	12,276	12,276	12,276	114,402	170,047	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	64,977	151,208	
Arizona, Tribal Agriculture	CCS Comparative Baseline[1]	15,586	22,254								
	No Action Alternative	12,419									
	Basic Coordination Alternative[2]	12,419	28,957	49,582							
	Enhanced Coordination Alternative	8,067	13,395	19,975	24,123	26,855	28,220	30,707	39,200		
	Maximum Operational Flexibility Alternative	6,535	16,804	28,237	40,341	48,486	53,560	61,787	64,022	66,506	68,054
	Supply Driven (LB Priority Approach) Alternative	6,535	16,804	28,237	40,341	48,486	53,560				
	Supply Driven (LB Pro Rata Approach) Alternative	15,794	23,239	32,270	35,438	37,551	38,605				
	Representative Preferred (2027-2028) Alternative[3]	6,535	16,804	28,237	40,341	48,486	53,560	61,787	64,022	66,506	
	Representative Preferred (2029-2060) Alternative[4]	12,419	28,957	49,582	61,862	61,922	62,201	62,922	65,447	67,375	
California, Tribal Agriculture	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	1,298	1,930	2,721	3,195	3,511	3,669	3,985	5,092		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	579	1,181	1,776	2,289	2,632	2,803				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Nevada, Tribal Agriculture	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	131	219	328	393	437	459	503	656		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	131	219	329	394	438	460				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-2
Annual Acres of Fallowed Cropland in the Analysis Area by Priority Group, Alternative, and Shortage Level, in kaf

State, Water Entitlement Holders, Priority Group	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture, Priority 4(i)	CCS Comparative Baseline[1]	1,695	2,747								
	No Action Alternative	1,222									
	Basic Coordination Alternative[2]	1,222	3,882	7,322							
	Enhanced Coordination Alternative	552	881	1,451	1,801	1,980	2,064	2,247	2,907		
	Maximum Operational Flexibility Alternative	464	2,007	3,764	5,591	7,063	8,074	9,854	10,275	10,275	10,275
	Supply Driven (LB Priority Approach) Alternative	464	2,007	3,764	5,591	7,063	8,074				
	Supply Driven (LB Pro Rata Approach) Alternative	1,087	1,723	2,369	2,615	2,779	2,861				
	Representative Preferred (2027-2028) Alternative[3]	464	2,007	3,764	5,591	7,063	8,074	9,854	10,275	10,275	
	Representative Preferred (2029-2060) Alternative[4]	1,222	3,882	7,322	10,108	10,275	10,275	10,275	10,275	10,275	
Arizona, Non-Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	6,494	10,823	16,234	19,831	23,176	24,849	29,066	45,142		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	19,214	64,754	92,791
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	12,800	18,796	32,033	38,023	42,016	44,013				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	19,214	64,754	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	2,016	8,840	41,004	80,757	
Arizona, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	2,023	3,372	5,058	6,176	7,212	7,730	9,033	13,995		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	3,988	5,856	9,949	11,798	13,030	13,647				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
California, Non-Tribal Agriculture, Priorities 2 & 3	CCS Comparative Baseline[1]	0	3,305								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	14,691	22,485	32,228	38,074	41,971	43,920	47,817	62,376		
	Maximum Operational Flexibility Alternative	0	0	12,276	12,276	12,276	12,276	12,276	114,402	170,047	226,560
	Supply Driven (LB Priority Approach) Alternative	0	0	12,276	12,276	12,276	12,276				
	Supply Driven (LB Pro Rata Approach) Alternative	7,395	13,255	20,581	26,911	31,131	33,240				
	Representative Preferred (2027-2028) Alternative[3]	0	0	12,276	12,276	12,276	12,276	12,276	114,402	170,047	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	64,977	151,208	
California, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	56,650	83,179	116,339	136,235	149,500	156,132	169,396	220,986		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	31,818	51,765	76,698	98,241	112,603	119,784				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Arizona, Tribal Agriculture, Priorities CAP Indian & 4(i)	CCS Comparative Baseline[1]	15,586	22,254								
	No Action Alternative	12,419									
	Basic Coordination Alternative[2]	12,419	28,957	49,582							
	Enhanced Coordination Alternative	4,568	7,564	11,228	13,627	15,237	16,042	17,496	22,401		
	Maximum Operational Flexibility Alternative	6,535	16,804	28,237	40,341	48,486	53,560	61,787	61,922	61,922	61,922
	Supply Driven (LB Priority Approach) Alternative	6,535	16,804	28,237	40,341	48,486	53,560				
	Supply Driven (LB Pro Rata Approach) Alternative	8,897	13,112	18,405	20,240	21,455	22,059				
	Representative Preferred (2027-2028) Alternative[3]	6,535	16,804	28,237	40,341	48,486	53,560	61,787	61,922	61,922	
	Representative Preferred (2029-2060) Alternative[4]	12,419	28,957	49,582	61,862	61,922	61,922	61,922	61,922	61,922	
Arizona, Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	693	1,154	1,732	2,078	2,309	2,424	2,655	3,463		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	2,100	4,584	6,132
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	1,365	2,005	2,804	3,106	3,306	3,407				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	2,100	4,584	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	279	1,000	3,525	5,453	
Arizona, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	2,806	4,677	7,015	8,418	9,309	9,753	10,555	13,336		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	5,531	8,122	11,060	12,092	12,790	13,139				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
California, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	1,298	1,930	2,721	3,195	3,511	3,669	3,985	5,092		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	579	1,181	1,776	2,289	2,632	2,803				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Nevada, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	131	219	328	393	437	459	503	656		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	131	219	329	394	438	460				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

For California and Nevada tribal entitlement holders, impacts on fallowed lands would only occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. The largest impacts would occur under the Enhanced Coordination Alternative, during a shortage of 3.0 maf, with an increase in fallowed lands of about 6,000 acres (about 5,000 acres and 700 acres of fallowed lands in California and Nevada, respectively). There are no expected impacts on fallowed lands under all other alternatives and the CCS Comparative Baseline for California and Nevada tribal entitlement holders, including under the Representative Preferred Alternative (see **Figure TA 16-1**).

Overall, across all entitlement groups and states, during maximum levels of shortage, there would be large impacts on the agriculture sector, including large reductions in harvested acres and crop production, under the Maximum Operational Flexibility, the Representative Preferred (2029-2060), the Enhanced Coordination, and the Supply Driven (LB Pro Rata approach) Alternatives. Under the Maximum Operational Flexibility Alternative, during a shortage of 4.0 maf, about half of all harvested acres in Yuma County, Arizona would be fallowed (including almost all harvested acres of alfalfa, cotton, other hay and haylage, and small grains) as well as over 40 percent of all harvested acres in Pima County, Arizona and over 60 percent of all harvested acres in Riverside County, California would be fallowed. During a shortage of 3.6 maf under the Representative Preferred (2029-2060) Alternative, over 40 percent of all harvested acres in Yuma County, Arizona would be fallowed (including almost all harvested acres of alfalfa, cotton, and small grains) as well as over 40 percent of all harvested acres in Pima County, Arizona and over 60 percent of all harvested acres in Riverside County, California would be fallowed. During a shortage of 3.0 maf under the Enhanced Coordination Alternative, almost half of the harvested acres in Imperial County, California would be fallowed (including all harvested acres of alfalfa, crucifers, and field grains in the county), about half of all harvested acres in Clark County, Nevada would be fallowed (including about 80 percent of harvested acres of alfalfa), all harvested acres of alfalfa and cotton in Yuma County, Arizona would be fallowed, about 90 percent of field grain and small grain crops in La Paz, Arizona would be fallowed, and over 80 percent of alfalfa would be fallowed in Riverside, California. During a shortage of 2.1 maf under the Supply Driven Alternative (LB Pro Rata approach), about one third of the harvested acres would be fallowed in Clark County in Nevada and Mohave and Yuma Counties in Arizona (including all harvested acres of alfalfa and cotton in Yuma County) as well as all harvested acres of crucifers and field grains in Imperial County, California and about 90 percent of field grain and small grain crops in La Paz, Arizona would be fallowed.

Within each state and tribal and non-tribal agricultural entitlement group, impacts on fallowed cropland from change in water shortages across the alternatives and the CCS Comparative Baseline vary across priority groups. **Figure TA 16-2** reports the estimated number of agricultural acres fallowed for each priority group across alternatives and the CCS Comparative Baseline at a range of shortage volumes (Priorities 2 and 3 for California non-tribal agricultural entitlement holders were grouped together, as were the CAP Indian and 4(i) priorities for Arizona tribal agricultural entitlement holders, due to the similarities in the distribution of shortages). See **Appendix C** for shortages by individual entitlement holder.

Impacts on fallowed cropland from changes in water availability for the present perfected right (PPR) priority entitlement holders (both tribal and non-tribal agricultural entitlement holders) in Arizona, California, and Nevada followed the same trends across alternatives and the CCS

Comparative Baseline as discussed for California and Nevada tribal entitlement holders, above. The greatest impacts would occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, and there are no expected impacts on fallowed lands under all other alternatives and the CCS Comparative Baseline (see **Figure TA 16-2**).

For Arizona priority 3 tribal and non-tribal agricultural entitlement holders, during shortages less than or equal to 2.0 maf, the greatest impacts on fallowed lands would occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives and there are no expected impacts on fallowed lands under all other alternatives and the CCS Comparative Baseline. For shortages greater than 2.0 maf, in addition to the impacts that would occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, there would also be impacts on fallowed cropland under the Representative Preferred (2029-2060) alternative, and for shortages greater than or equal to 3.0 maf, there would be impacts on fallowed lands under the Maximum Operational Flexibility Alternative and potential impacts on fallowed lands under the Representative Preferred (2027-2028) Alternative. During a maximum level of shortage, across all alternatives and the CCS Comparative Baseline, the Maximum Operational Flexibility Alternative would result in the greatest level of impacts on fallowed lands, with an increase of about 6,000 acres and 93,000 acres of fallowed lands for Arizona priority 3 tribal and non-tribal agricultural entitlement holders, respectively, during a maximum shortage of 4.0 maf.

For Arizona priority 4(i) non-tribal and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders, during shortages of 0.6 maf, the greatest impact on fallowed lands occurs under the CCS Comparative Baseline and the No Action, Basic Coordination, and Representative Preferred (2029-2060) Alternatives; during shortages greater than 0.6 and less than or equal to 2.0 maf, the greatest impact occurs under the Basic Coordination and Representative Preferred (2029-2060) Alternatives; during shortages greater than 2.0 maf, the greatest impact on fallowed lands occurs under the Maximum Operational Flexibility and Representative Preferred (2029-2060) Alternatives, with the greatest increase in fallowed lands of about 10,000 acres and 62,000 acres for Arizona priority 4(i) non-tribal and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders, respectively, during a shortage of 4.0 maf under the Maximum Operational Flexibility Alternative or during a shortage of 3.6 maf under the Representative Preferred (2029-2060) Alternative. During the maximum levels of shortage, the smallest impact on fallowed croplands would occur under the No Action Alternative for Arizona priority 4(i) non-tribal and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders (with an increase in fallowed land of about 1,000 acres and 12,000 acres, with a shortage of 0.6 maf, for Arizona priority 4(i) non-tribal and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders, respectively).

For California priorities 2 and 3 non-tribal agricultural entitlement holders, the greatest impact on fallowed lands, during shortages under 3.0 maf, occurs under the Enhanced Coordination Alternative, and the greatest impact, during shortages greater than or equal to 3.0 maf, occurs under the Maximum Operational Flexibility and Representative Preferred Alternatives, with the largest increase in fallowed land under the Maximum Operational Flexibility Alternative of about 227,000 acres, with a shortage of 4.0 maf. The No Action and Basic Coordination Alternatives would result in the lowest impacts on fallowed lands due to maximum levels of shortage, with no expected

increase in fallowed land across California priorities 2 and 3 non-tribal agricultural entitlement holders (see **Figure TA 16-2**).

For more information on impacts on changing land use and water deliveries due to potential long-term water shortages to irrigation entitlement holders, see **TA 4**, Water Deliveries, and **TA 17**, Population and Land Use.

Figure TA 16-3 shows the estimated loss in market value of crops due to water shortages and fallowed lands for each alternative and the CCS Comparative Baseline across a range of shortage volumes (0.6 maf to 4.0 maf) for Arizona, California, and Nevada non-tribal and tribal irrigation entitlement holders, and **Figure TA 16-4** presents the estimated loss in market value of crops separated by priority group in each state in the analysis area (see **Appendix C** for shortages by individual entitlement holder). The patterns in loss of market values across regions, non-tribal and tribal entitlement holders, and shortage levels are similar to those discussed for fallowed acres, except for California non-tribal agricultural entitlement holders, as discussed below. On average, for Arizona non-tribal and tribal entitlement holders, the Maximum Operational Flexibility Alternative would result in the largest level of impacts on market value of crops during a maximum level of shortage compared with the other alternatives and CCS Comparative Baseline, with a reduction in market value of crops of about $150.8 million and $113.2 million, during a shortage of 4.0 maf, for Arizona non-tribal and Arizona tribal entitlement holders, respectively. Under the Representative Preferred (2029-2060) Alternative, Arizona non-tribal and tribal entitlement holders could see a reduction in market value of crops of about $133.1 million and $111.9 million, respectively, during a maximum level of shortage of 3.6 maf. The smallest level of impacts on market value of crops during a maximum level of shortage would occur under the No Action Alternative for Arizona non-tribal and tribal entitlement holders, on average, with a reduction in market value of crops of about $1.8 million and $17.4 million, during a shortage of 0.6 maf, for Arizona non-tribal and Arizona tribal entitlement holders, respectively. However, this varies for certain priority groups within Arizona non-tribal and tribal entitlement holders. For Arizona priority 4(i) non-tribal entitlement holders and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders, the trends in impacts on market value of crops during a maximum level of shortage across alternatives would be the same as discussed above for all Arizona non-tribal and tribal entitlement holders, with the largest level of impacts on market value of crops occurring under the Maximum Operational Flexibility and Representative Preferred Alternatives (with a maximum level of reduction in market value of crops of about $32.3 million and $103.5 million, for Arizona priority 4(i) non-tribal entitlement holders and Arizona CAP Indian and 4(i) priority tribal entitlement holders, respectively) and the smallest level of impacts on market value of crops during a maximum level of shortage occurring under the No Action Alternative (with a reduction in market value of crops of about $1.8 million and $17.4 million, for Arizona priority 4(i) non-tribal entitlement holders and Arizona CAP Indian and 4(i) priority tribal entitlement holders, respectively). For Arizona priority 3 tribal and non-tribal agricultural entitlement holders, the largest level of impacts on market value of crops would occur under the Maximum Operational Flexibility Alternative (with a reduction in market value of crops of about $118.4 million and $9.7 million for Arizona priority 3 tribal and non-tribal agricultural entitlement holders, respectively) and there are no expected impacts on market value of crops under the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives. For Arizona PPR priority tribal and non-tribal agricultural

entitlement holders, the only impacts on market value of crops would occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives.

For California non-tribal entitlement holders, although the Enhanced Coordination Alternative had the highest level of impact on fallowed lands during the maximum level of shortage, the Maximum Operational Flexibility Alternative would result in the largest level of impacts on market value of crops during a maximum level of shortage (with a reduction in market value of crops of about $1,094.3 million) due to a greater number of acres of higher-valued crops being fallowed (especially for the entitlement holders within priorities 2 and 3). Under the Representative Preferred (2029-2060) Alternative, California non-tribal entitlement holders could see a reduction in market value of crops of about $812.7 million, during a maximum level of shortage of 3.6 maf. There are not expected to be impacts on market value of crops under the No Action and Basic Coordination Alternatives for California non-tribal entitlement holders. As discussed above for Arizona, these impacts on market value of crops for California non-tribal agriculture entitlement holders vary across priority groups. For California priority group 2 and 3 non-tribal agricultural entitlement holders, the largest level of impacts on market value of crops would occur under the Maximum Operational Flexibility Alternative (with a reduction in market value of crops of about $1,094.3 million), whereas for California PPR priority non-tribal agricultural entitlement holders, the largest level of impacts on market value of crops would occur under the Enhanced Coordination Alternative (with a reduction in market value of crops of about $546.8 million).

As discussed above for impacts on fallowed lands, for the tribal agricultural entitlement holders in California and Nevada (all of whom have PPR priority), impacts on the market value of crops would only occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, with the largest level of impacts on market value of crops during a maximum level of shortage occurring under the Enhanced Coordination Alternative.

Figure TA 16-3
Annual Loss of Direct Market Value of Agricultural Production in the Analysis Area by Alternative and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture	CCS Comparative Baseline[1]	2.5	4.2								
	No Action Alternative	1.8									
	Basic Coordination Alternative[2]	1.8	5.9	17.6							
	Enhanced Coordination Alternative	13.0	21.7	32.7	40.4	48.3	52.3	58.9	79.6		
	Maximum Operational Flexibility Alternative	0.6	2.9	5.8	8.8	16.3	21.0	30.1	60.0	111.0	150.8
	Supply Driven (LB Priority Approach) Alternative	0.6	2.9	5.8	8.8	16.3	21.0				
	Supply Driven (LB Pro Rata Approach) Alternative	25.7	37.9	62.7	70.4	75.6	78.2				
	Representative Preferred (2027-2028) Alternative[3]	0.6	2.9	5.8	8.8	16.3	21.0	30.1	60.0	111.0	
	Representative Preferred (2029-2060) Alternative[4]	1.8	5.9	17.6	31.5	32.3	35.2	45.0	88.7	133.1	
California, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0.0	6.8								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	329.8	390.3	466.0	511.4	541.6	556.8	587.0	691.8		
	Maximum Operational Flexibility Alternative	0.0	0.0	25.4	25.4	25.4	25.4	25.4	733.7	843.3	1,094.3
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	25.4	25.4	25.4	25.4				
	Supply Driven (LB Pro Rata Approach) Alternative	273.1	318.7	375.5	424.7	457.5	473.8				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	25.4	25.4	25.4	25.4	25.4	733.7	843.3	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	186.9	812.7	
Arizona, Tribal Agriculture	CCS Comparative Baseline[1]	21.7	31.3								
	No Action Alternative	17.4									
	Basic Coordination Alternative[2]	17.4	43.2	82.3							
	Enhanced Coordination Alternative	11.4	18.2	26.9	32.2	35.5	37.2	40.7	52.5		
	Maximum Operational Flexibility Alternative	9.7	23.4	41.9	64.3	80.4	88.7	102.3	106.3	110.2	113.2
	Supply Driven (LB Priority Approach) Alternative	9.7	23.4	41.9	64.3	80.4	88.7				
	Supply Driven (LB Pro Rata Approach) Alternative	21.3	31.0	42.8	47.3	50.2	51.7				
	Representative Preferred (2027-2028) Alternative[3]	9.7	23.4	41.9	64.3	80.4	88.7	102.3	106.3	110.2	
	Representative Preferred (2029-2060) Alternative[4]	17.4	43.2	82.3	103.1	103.5	103.9	104.8	108.2	111.9	
California, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	5.6	6.4	7.6	8.2	8.7	8.9	9.4	10.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	2.8	5.4	6.2	7.0	7.4	7.7				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.1	0.2	0.3	0.4	0.4	0.5				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-4
Annual Loss of Direct Market Value of Agricultural Production in the Analysis Area by Priority Group, Alternative, and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders, Priority Group	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture, Priority 4(i)	CCS Comparative Baseline[1]	2.5	4.2								
	No Action Alternative	1.8									
	Basic Coordination Alternative[2]	1.8	5.9	17.6							
	Enhanced Coordination Alternative	0.8	1.3	2.1	2.6	2.9	3.0	3.3	4.3		
	Maximum Operational Flexibility Alternative	0.6	2.9	5.8	8.8	16.3	21.0	30.1	32.3	32.3	32.3
	Supply Driven (LB Priority Approach) Alternative	0.6	2.9	5.8	8.8	16.3	21.0				
	Supply Driven (LB Pro Rata Approach) Alternative	1.6	2.5	3.5	3.9	4.1	4.2				
	Representative Preferred (2027-2028) Alternative[3]	0.6	2.9	5.8	8.8	16.3	21.0	30.1	32.3	32.3	
	Representative Preferred (2029-2060) Alternative[4]	1.8	5.9	17.6	31.5	32.3	32.3	32.3	32.3	32.3	
Arizona, Non-Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	9.3	15.6	23.3	28.8	34.6	37.5	42.3	57.4		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.6	78.7	118.4
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	18.4	27.0	45.1	50.7	54.5	56.4				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.6	78.7	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	2.9	12.7	56.4	100.7	
Arizona, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	2.9	4.9	7.3	9.0	10.8	11.7	13.2	17.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	5.8	8.5	14.1	15.8	17.0	17.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Non-Tribal Agriculture, Priorities 2 & 3	CCS Comparative Baseline[1]	0.0	6.8								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	57.9	72.5	90.7	101.6	108.9	112.5	119.8	145.1		
	Maximum Operational Flexibility Alternative	0.0	0.0	25.4	25.4	25.4	25.4	25.4	733.7	843.3	1,094.3
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	25.4	25.4	25.4	25.4				
	Supply Driven (LB Pro Rata Approach) Alternative	44.3	55.2	68.9	80.7	88.6	92.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	25.4	25.4	25.4	25.4	25.4	733.7	843.3	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	186.9	812.7	
California, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	271.9	317.9	375.3	409.8	432.8	444.3	467.3	546.8		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	228.8	263.4	306.6	344.0	368.8	381.3				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Arizona, Tribal Agriculture, Priorities CAP Indian & 4(i)	CCS Comparative Baseline[1]	21.7	31.3								
	No Action Alternative	17.4									
	Basic Coordination Alternative[2]	17.4	43.2	82.3							
	Enhanced Coordination Alternative	7.0	10.9	15.9	19.0	21.0	22.0	24.0	30.7		
	Maximum Operational Flexibility Alternative	9.7	23.4	41.9	64.3	80.4	88.7	102.3	103.5	103.5	103.5
	Supply Driven (LB Priority Approach) Alternative	9.7	23.4	41.9	64.3	80.4	88.7				
	Supply Driven (LB Pro Rata Approach) Alternative	12.7	18.4	25.2	27.7	29.4	30.3				
	Representative Preferred (2027-2028) Alternative[3]	9.7	23.4	41.9	64.3	80.4	88.7	102.3	103.5	103.5	
	Representative Preferred (2029-2060) Alternative[4]	17.4	43.2	82.3	103.1	103.5	103.5	103.5	103.5	103.5	
Arizona, Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.9	1.5	2.3	2.7	3.0	3.2	3.5	4.5		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	6.7	9.7
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	1.8	2.6	3.7	4.1	4.3	4.5				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	6.7	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.4	1.3	4.6	8.4	
Arizona, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	3.5	5.8	8.7	10.4	11.5	12.0	13.2	17.2		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	6.8	10.0	13.9	15.5	16.5	16.9				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	5.6	6.4	7.6	8.2	8.7	8.9	9.4	10.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	2.8	5.4	6.2	7.0	7.4	7.7				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.1	0.2	0.3	0.4	0.4	0.5				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

As agricultural entitlement holders fallow lands due to water shortages, the loss in market value of crops would likely lead to reductions in economic contributions in the region across agricultural-related sectors as well as sectors that supply goods and services to the farmers and their households. The impacts on economic contributions, such as jobs, labor income and total economic output, across the alternatives and the CCS Comparative Baseline would follow similar patterns as those described for impacts on fallowed lands and market values of crops.[9] **Figure TA 16-5**, **Figure TA 16-7**, and **Figure TA 16-9** show the results of the impact analysis on total jobs, labor income, and economic output, respectively, including direct, indirect, and induced impacts, by state and type of entitlement holder, and **Figure TA 16-6**, **Figure TA 16-8**, and **Figure TA 16-10** present the impacts on total jobs, labor income, and economic output, respectively, separated by priority group (see **Appendix C** for shortages by individual entitlement holder). On average, for non-tribal and tribal entitlement holders in Arizona, the greatest impacts on jobs, labor income, and total economic output due to a maximum level of shortage occurs under the Maximum Operational Flexibility Alternative, during a shortage of 4.0 maf, with annual reductions of about 1,000 jobs, $56.5 million in labor income, and $237.7 million in economic output for non-tribal agricultural entitlement holders in Arizona, and annual reductions of about 1,000 jobs, $64.7 million in labor income, and $222.6 million in economic output for tribal entitlement holders in Arizona. Under the Representative Preferred (2029-2060) Alternative, Arizona non-tribal entitlement holders could see a reduction of about 900 jobs, $50.5 million in labor income, and $210.7 million in economic output and Arizona tribal entitlement holders could see a reduction of about 1,000 jobs, $64.0 million in labor income, and $220.0 million in economic output, during a maximum level of shortage of 3.6 maf. The lowest impacts on jobs, labor income, and economic output for non-tribal and tribal entitlement holders in Arizona, during a maximum level of shortage, occurs under the No Action Alternative, during a shortage of 0.6 maf, with annual reductions of about 10 jobs, $0.6 million in labor income, and $2.8 million in economic output for non-tribal agricultural entitlement holders in Arizona, and annual reductions of about 140 jobs, $10.7 million in labor income, and $34.8 million in economic output for tribal entitlement holders in Arizona. However, as discussed under impacts on market values of crops, the impacts on jobs, labor income, and economic output vary across priority groups within Arizona non-tribal and tribal entitlement holders. For Arizona priority 4(i) non-tribal entitlement holders and Arizona CAP Indian and 4(i) priority tribal agricultural entitlement holders, the trends in impacts on jobs, labor income, and economic output during a maximum level of shortage across alternatives would be the same as discussed above for all Arizona non-tribal and tribal entitlement holders, with the largest level of impacts on jobs, labor income, and economic output occurring under the Maximum Operational Flexibility and Representative Preferred Alternatives and the smallest level of impacts on jobs, income, and output during a maximum level of shortage occurring under the No Action Alternative. For Arizona priority 3 tribal and non-tribal agricultural entitlement holders, the largest level of impacts on jobs, labor income, and economic output would occur under the Maximum Operational Flexibility Alternative and there are no expected impacts on jobs, income, and output under the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternative. For Arizona

[9] Some third-party studies have been conducted on the impacts on economic conditions from changes in agriculture under specific scenarios and assumptions. For example, Imperial County Workforce and Economic Development conducted an analysis that highlights the potential ranges of impacts on Imperial County's economy from changes in irrigation water. Because this study is scenario-specific and not directly comparable to the Draft EIS modeling framework, the FEIS does not adopt quantified estimates from this study.

PPR priority tribal and non-tribal agricultural entitlement holders, the only impacts on jobs, labor income, and economic output would occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives.

For non-tribal entitlement holders in California, the greatest impacts on jobs, labor income, and total economic output due to a maximum level of shortage occurs under the Maximum Operational Flexibility Alternative, during a shortage of 4.0 maf, with annual reductions of about 11,000 jobs, $824.7 million in labor income, and $1,755.2 million in economic output. Under the Representative Preferred (2029-2060) Alternative, California non-tribal entitlement holders could see a reduction of about 9,000 jobs, $718.1 million in labor income, and $1,343.9 million in economic output, during a maximum level of shortage of 3.6 maf. There are not expected to be impacts on jobs, labor income, and total economic output under the No Action and Basic Coordination Alternatives for California non-tribal entitlement holders. As discussed above for Arizona, these impacts on jobs, labor income, and economic output for California non-tribal agriculture entitlement holders vary across priority group. For California priority group 2 and 3 non-tribal agricultural entitlement holders, the largest level of impacts on jobs, labor income, and economic output would occur under the Maximum Operational Flexibility Alternative, whereas for California PPR priority non-tribal agricultural entitlement holders, the largest level of impacts on jobs, labor income, and economic output would occur under the Enhanced Coordination Alternative.

For California and Nevada tribal entitlement holders (all of whom have PPR priority), impacts on economic contributions such as jobs, labor income, and economic output, would be greatest under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, with impacts as large as a reduction of over 60 jobs, about $3.9 million in labor income, and $15.9 million in total economic output for tribal entitlement holders in California, under the Enhanced Coordination Alternative, with a shortage of 3.0 maf; for Nevada tribal entitlement holders, under the same alternative and shortage level, there would be an estimated reduction of over 10 jobs, about $0.1 million in labor income, and $0.9 million in total economic output. There are no expected impacts on economic contributions under all other alternatives, including the CCS Comparative Baseline and Representative Preferred Alternative.

Figure TA 16-5
Annual Loss of Total Jobs from Agricultural Production in the Analysis Area by Alternative and Shortage Level, in kaf

State, Water Entitlement Holders	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture	CCS Comparative Baseline[1]	18	31								
	No Action Alternative	13									
	Basic Coordination Alternative[2]	13	43	135							
	Enhanced Coordination Alternative	100	166	251	305	347	368	405	525		
	Maximum Operational Flexibility Alternative	5	22	42	65	126	159	221	448	742	1,043
	Supply Driven (LB Priority Approach) Alternative	5	22	42	65	126	159				
	Supply Driven (LB Pro Rata Approach) Alternative	197	292	427	472	502	517				
	Representative Preferred (2027-2028) Alternative[3]	5	22	42	65	126	159	221	448	742	
	Representative Preferred (2029-2060) Alternative[4]	13	43	135	230	235	258	333	615	906	
California, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0	38								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	1,975	2,310	2,729	2,981	3,149	3,233	3,400	3,981		
	Maximum Operational Flexibility Alternative	0	0	141	141	141	141	141	8,459	9,080	10,560
	Supply Driven (LB Priority Approach) Alternative	0	0	141	141	141	141				
	Supply Driven (LB Pro Rata Approach) Alternative	1,661	1,913	2,228	2,500	2,682	2,773				
	Representative Preferred (2027-2028) Alternative[3]	0	0	141	141	141	141	141	8,459	9,080	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	2,122	8,908	
Arizona, Tribal Agriculture	CCS Comparative Baseline[1]	173	260								
	No Action Alternative	136									
	Basic Coordination Alternative[2]	136	404	860							
	Enhanced Coordination Alternative	99	156	231	275	304	318	349	456		
	Maximum Operational Flexibility Alternative	77	188	388	666	843	915	1,035	1,067	1,107	1,146
	Supply Driven (LB Priority Approach) Alternative	77	188	388	666	843	915				
	Supply Driven (LB Pro Rata Approach) Alternative	184	266	368	408	435	449				
	Representative Preferred (2027-2028) Alternative[3]	77	188	388	666	843	915	1,035	1,067	1,107	
	Representative Preferred (2029-2060) Alternative[4]	136	404	860	1,042	1,046	1,049	1,056	1,081	1,129	
California, Tribal Agriculture	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	33	38	45	48	51	52	55	63		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	17	32	37	41	44	45				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Nevada, Tribal Agriculture	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	3	4	6	8	9	9	10	13		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	3	4	6	8	9	9				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-6
Annual Loss of Total Jobs from Agricultural Production in the Analysis Area by Priority Group, Alternative, and Shortage Level, in kaf

State, Water Entitlement Holders, Priority Group	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture, Priority 4(i)	CCS Comparative Baseline[1]	18	31								
	No Action Alternative	13									
	Basic Coordination Alternative[2]	13	43	135							
	Enhanced Coordination Alternative	5	9	15	19	21	22	24	31		
	Maximum Operational Flexibility Alternative	5	22	42	65	126	159	221	235	235	235
	Supply Driven (LB Priority Approach) Alternative	5	22	42	65	126	159				
	Supply Driven (LB Pro Rata Approach) Alternative	11	18	26	28	30	31				
	Representative Preferred (2027-2028) Alternative[3]	5	22	42	65	126	159	221	235	235	
	Representative Preferred (2029-2060) Alternative[4]	13	43	135	230	235	235	235	235	235	
Arizona, Non-Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	72	120	180	218	248	264	290	376		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	213	507	808
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	142	208	306	338	359	370				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	213	507	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	22	98	380	671	
Arizona, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	23	38	56	68	78	82	91	118		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	44	65	96	106	112	116				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
California, Non-Tribal Agriculture, Priorities 2 & 3	CCS Comparative Baseline[1]	0	38								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	343	424	525	585	625	646	686	826		
	Maximum Operational Flexibility Alternative	0	0	141	141	141	141	141	8,459	9,080	10,560
	Supply Driven (LB Priority Approach) Alternative	0	0	141	141	141	141				
	Supply Driven (LB Pro Rata Approach) Alternative	268	328	404	470	513	535				
	Representative Preferred (2027-2028) Alternative[3]	0	0	141	141	141	141	141	8,459	9,080	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	2,122	8,908	
California, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	1,631	1,886	2,205	2,396	2,523	2,587	2,714	3,155		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	1,393	1,584	1,824	2,031	2,169	2,238				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Arizona, Tribal Agriculture, Priorities CAP Indian & 4(i)	CCS Comparative Baseline[1]	173	260								
	No Action Alternative	136									
	Basic Coordination Alternative[2]	136	404	860							
	Enhanced Coordination Alternative	57	86	126	149	165	172	189	248		
	Maximum Operational Flexibility Alternative	77	188	388	666	843	915	1,035	1,046	1,046	1,046
	Supply Driven (LB Priority Approach) Alternative	77	188	388	666	843	915				
	Supply Driven (LB Pro Rata Approach) Alternative	101	145	199	221	236	244				
	Representative Preferred (2027-2028) Alternative[3]	77	188	388	666	843	915	1,035	1,046	1,046	
	Representative Preferred (2029-2060) Alternative[4]	136	404	860	1,042	1,046	1,046	1,046	1,046	1,046	
Arizona, Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	7	11	17	21	23	24	26	34		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	21	61	100
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	14	20	28	31	33	34				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	21	61	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	3	10	35	83	
Arizona, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	35	58	88	105	116	122	134	174		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	69	102	141	156	166	171				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
California, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	33	38	45	48	51	52	55	63		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	17	32	37	41	44	45				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	
Nevada, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0	0								
	No Action Alternative	0									
	Basic Coordination Alternative[2]	0	0	0							
	Enhanced Coordination Alternative	3	4	6	8	9	9	10	13		
	Maximum Operational Flexibility Alternative	0	0	0	0	0	0	0	0	0	0
	Supply Driven (LB Priority Approach) Alternative	0	0	0	0	0	0				
	Supply Driven (LB Pro Rata Approach) Alternative	3	4	6	8	9	9				
	Representative Preferred (2027-2028) Alternative[3]	0	0	0	0	0	0	0	0	0	
	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	0	0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-7
Annual Loss of Labor Income from Agricultural Production in the Analysis Area by Alternative and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0.9	1.5								
	No Action Alternative	0.6									
	Basic Coordination Alternative[2]	0.6	2.1	8.1							
	Enhanced Coordination Alternative	4.4	7.4	11.1	13.9	17.2	18.8	21.3	29.0		
	Maximum Operational Flexibility Alternative	0.2	1.0	2.0	3.0	7.6	9.5	13.3	23.6	42.9	56.5
	Supply Driven (LB Priority Approach) Alternative	0.2	1.0	2.0	3.0	7.6	9.5				
	Supply Driven (LB Pro Rata Approach) Alternative	8.8	12.9	22.7	25.6	27.5	28.4				
	Representative Preferred (2027-2028) Alternative[3]	0.2	1.0	2.0	3.0	7.6	9.5	13.3	23.6	42.9	
	Representative Preferred (2029-2060) Alternative[4]	0.6	2.1	8.1	13.8	14.2	15.1	18.5	34.7	50.5	
California, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0.0	2.3								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	125.2	145.4	170.8	186.0	196.2	201.2	211.4	246.5		
	Maximum Operational Flexibility Alternative	0.0	0.0	8.5	8.5	8.5	8.5	8.5	690.5	728.6	824.7
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	8.5	8.5	8.5	8.5				
	Supply Driven (LB Pro Rata Approach) Alternative	106.2	121.4	140.5	157.0	168.0	173.4				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	8.5	8.5	8.5	8.5	8.5	690.5	728.6	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	174.0	718.1	
Arizona, Tribal Agriculture	CCS Comparative Baseline[1]	13.4	19.3								
	No Action Alternative	10.7									
	Basic Coordination Alternative[2]	10.7	25.9	48.1							
	Enhanced Coordination Alternative	6.6	10.6	15.8	18.9	20.9	21.8	23.9	31.2		
	Maximum Operational Flexibility Alternative	5.9	14.4	25.2	37.6	47.1	51.3	58.2	60.7	63.0	64.7
	Supply Driven (LB Priority Approach) Alternative	5.9	14.4	25.2	37.6	47.1	51.3				
	Supply Driven (LB Pro Rata Approach) Alternative	12.5	18.3	25.3	28.0	29.8	30.7				
	Representative Preferred (2027-2028) Alternative[3]	5.9	14.4	25.2	37.6	47.1	51.3	58.2	60.7	63.0	
	Representative Preferred (2029-2060) Alternative[4]	10.7	25.9	48.1	58.7	58.9	59.1	59.8	61.9	64.0	
California, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	2.1	2.4	2.8	3.0	3.2	3.2	3.4	3.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	1.1	2.1	2.3	2.6	2.8	2.8				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.0	0.0	0.1	0.1	0.1	0.1				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-8
Annual Loss of Labor Income from Agricultural Production in the Analysis Area by Priority Group, Alternative, and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders, Priority Group	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture, Priority 4(i)	CCS Comparative Baseline[1]	0.9	1.5								
	No Action Alternative	0.6									
	Basic Coordination Alternative[2]	0.6	2.1	8.1							
	Enhanced Coordination Alternative	0.3	0.4	0.7	0.9	1.0	1.1	1.2	1.5		
	Maximum Operational Flexibility Alternative	0.2	1.0	2.0	3.0	7.6	9.5	13.3	14.2	14.2	14.2
	Supply Driven (LB Priority Approach) Alternative	0.2	1.0	2.0	3.0	7.6	9.5				
	Supply Driven (LB Pro Rata Approach) Alternative	0.5	0.9	1.2	1.4	1.4	1.5				
	Representative Preferred (2027-2028) Alternative[3]	0.2	1.0	2.0	3.0	7.6	9.5	13.3	14.2	14.2	
	Representative Preferred (2029-2060) Alternative[4]	0.6	2.1	8.1	13.8	14.2	14.2	14.2	14.2	14.2	
Arizona, Non-Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	3.2	5.3	7.9	9.9	12.3	13.5	15.3	20.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	28.8	42.3
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	6.3	9.2	16.4	18.5	19.8	20.5				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	28.8	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	1.0	4.3	20.5	36.3	
Arizona, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	1.0	1.7	2.5	3.1	3.8	4.2	4.8	6.5		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	2.0	2.9	5.1	5.7	6.2	6.4				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Non-Tribal Agriculture, Priorities 2 & 3	CCS Comparative Baseline[1]	0.0	2.3								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	21.6	26.5	32.6	36.3	38.7	39.9	42.4	50.8		
	Maximum Operational Flexibility Alternative	0.0	0.0	8.5	8.5	8.5	8.5	8.5	690.5	728.6	824.7
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	8.5	8.5	8.5	8.5				
	Supply Driven (LB Pro Rata Approach) Alternative	17.1	20.7	25.3	29.3	31.9	33.2				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	8.5	8.5	8.5	8.5	8.5	690.5	728.6	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	174.0	718.1	
California, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	103.5	118.9	138.2	149.8	157.5	161.3	169.0	195.7		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	89.1	100.7	115.2	127.7	136.0	140.2				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Arizona, Tribal Agriculture, Priorities CAP Indian & 4(i)	CCS Comparative Baseline[1]	13.4	19.3								
	No Action Alternative	10.7									
	Basic Coordination Alternative[2]	10.7	25.9	48.1							
	Enhanced Coordination Alternative	4.2	6.6	9.9	11.8	13.0	13.6	14.8	19.0		
	Maximum Operational Flexibility Alternative	5.9	14.4	25.2	37.6	47.1	51.3	58.2	58.9	58.9	58.9
	Supply Driven (LB Priority Approach) Alternative	5.9	14.4	25.2	37.6	47.1	51.3				
	Supply Driven (LB Pro Rata Approach) Alternative	7.8	11.4	15.6	17.2	18.2	18.7				
	Representative Preferred (2027-2028) Alternative[3]	5.9	14.4	25.2	37.6	47.1	51.3	58.2	58.9	58.9	
	Representative Preferred (2029-2060) Alternative[4]	10.7	25.9	48.1	58.7	58.9	58.9	58.9	58.9	58.9	
Arizona, Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.6	1.0	1.5	1.8	2.0	2.1	2.3	2.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	4.1	5.8
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	1.2	1.7	2.4	2.6	2.8	2.9				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	4.1	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.2	0.9	3.0	5.1	
Arizona, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	1.8	3.0	4.4	5.3	5.9	6.2	6.8	9.2		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	3.5	5.1	7.3	8.2	8.8	9.1				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	2.1	2.4	2.8	3.0	3.2	3.2	3.4	3.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	1.1	2.1	2.3	2.6	2.8	2.8				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.0	0.0	0.1	0.1	0.1	0.1				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-9
Annual Loss of Total Economic Output from Agricultural Production in the Analysis Area by Alternative and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture	CCS Comparative Baseline[1]	3.8	6.5								
	No Action Alternative	2.8									
	Basic Coordination Alternative[2]	2.8	9.2	27.4							
	Enhanced Coordination Alternative	19.9	33.1	50.0	61.8	74.2	80.3	91.2	126.8		
	Maximum Operational Flexibility Alternative	1.0	4.5	8.9	13.6	25.4	32.6	46.5	91.9	176.6	237.7
	Supply Driven (LB Priority Approach) Alternative	1.0	4.5	8.9	13.6	25.4	32.6				
	Supply Driven (LB Pro Rata Approach) Alternative	39.3	57.9	97.7	111.0	119.8	124.3				
	Representative Preferred (2027-2028) Alternative[3]	1.0	4.5	8.9	13.6	25.4	32.6	46.5	91.9	176.6	
	Representative Preferred (2029-2060) Alternative[4]	2.8	9.2	27.4	48.6	49.8	54.2	69.2	138.2	210.7	
California, Non-Tribal Agriculture	CCS Comparative Baseline[1]	0.0	9.9								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	479.9	567.9	677.8	743.7	787.6	809.6	853.6	1,005.8		
	Maximum Operational Flexibility Alternative	0.0	0.0	36.9	36.9	36.9	36.9	36.9	1,229.1	1,388.4	1,755.2
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	36.9	36.9	36.9	36.9				
	Supply Driven (LB Pro Rata Approach) Alternative	397.6	463.7	546.4	617.8	665.4	689.2				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	36.9	36.9	36.9	36.9	36.9	1,229.1	1,388.4	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	314.3	1,343.9	
Arizona, Tribal Agriculture	CCS Comparative Baseline[1]	43.5	62.5								
	No Action Alternative	34.8									
	Basic Coordination Alternative[2]	34.8	85.8	162.2							
	Enhanced Coordination Alternative	22.5	36.0	53.5	64.0	70.8	74.2	81.0	104.7		
	Maximum Operational Flexibility Alternative	19.4	46.8	83.3	126.8	158.5	174.6	201.0	209.0	216.7	222.6
	Supply Driven (LB Priority Approach) Alternative	19.4	46.8	83.3	126.8	158.5	174.6				
	Supply Driven (LB Pro Rata Approach) Alternative	42.4	61.8	85.4	94.2	100.1	103.0				
	Representative Preferred (2027-2028) Alternative[3]	19.4	46.8	83.3	126.8	158.5	174.6	201.0	209.0	216.7	
	Representative Preferred (2029-2060) Alternative[4]	34.8	85.8	162.2	202.6	203.4	204.1	206.0	212.7	220.0	
California, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	8.1	9.4	11.0	12.0	12.6	13.0	13.6	15.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	4.2	7.8	9.1	10.1	10.8	11.2				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.2	0.3	0.4	0.5	0.6	0.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Figure TA 16-10
Annual Loss of Total Economic Output from Agricultural Production in the Analysis Area by Priority Group, Alternative, and Shortage Level, in kaf (2025$ millions)

State, Water Entitlement Holders, Priority Group	Shortage Level (kaf)	600	1,000	1,500	1,800	2,000	2,100	2,300	3,000	3,600	4,000
Arizona, Non-Tribal Agriculture, Priority 4(i)	CCS Comparative Baseline[1]	3.8	6.5								
	No Action Alternative	2.8									
	Basic Coordination Alternative[2]	2.8	9.2	27.4							
	Enhanced Coordination Alternative	1.2	2.0	3.2	4.0	4.5	4.7	5.1	6.7		
	Maximum Operational Flexibility Alternative	1.0	4.5	8.9	13.6	25.4	32.6	46.5	49.8	49.8	49.8
	Supply Driven (LB Priority Approach) Alternative	1.0	4.5	8.9	13.6	25.4	32.6				
	Supply Driven (LB Pro Rata Approach) Alternative	2.4	3.8	5.4	6.0	6.4	6.6				
	Representative Preferred (2027-2028) Alternative[3]	1.0	4.5	8.9	13.6	25.4	32.6	46.5	49.8	49.8	
	Representative Preferred (2029-2060) Alternative[4]	2.8	9.2	27.4	48.6	49.8	49.8	49.8	49.8	49.8	
Arizona, Non-Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	14.2	23.7	35.6	44.0	53.1	57.7	65.6	91.5		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.1	126.8	187.9
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	28.1	41.2	70.4	80.0	86.5	89.7				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.1	126.8	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	4.4	19.4	88.4	160.9	
Arizona, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	4.5	7.4	11.1	13.8	16.6	18.0	20.4	28.5		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	8.8	12.9	21.9	24.9	26.9	27.9				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Non-Tribal Agriculture, Priorities 2 & 3	CCS Comparative Baseline[1]	0.0	9.9								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	84.3	105.4	131.8	147.7	158.2	163.5	174.1	210.8		
	Maximum Operational Flexibility Alternative	0.0	0.0	36.9	36.9	36.9	36.9	36.9	1,229.1	1,388.4	1,755.2
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	36.9	36.9	36.9	36.9				
	Supply Driven (LB Pro Rata Approach) Alternative	64.5	80.4	100.2	117.4	128.9	134.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	36.9	36.9	36.9	36.9	36.9	1,229.1	1,388.4	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	314.3	1,343.9	
California, Non-Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	395.7	462.4	545.9	596.0	629.4	646.1	679.5	795.0		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	333.1	383.4	446.1	500.4	536.5	554.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Arizona, Tribal Agriculture, Priorities CAP Indian & 4(i)	CCS Comparative Baseline[1]	43.5	62.5								
	No Action Alternative	34.8									
	Basic Coordination Alternative[2]	34.8	85.8	162.2							
	Enhanced Coordination Alternative	13.9	21.6	31.9	38.1	42.1	44.1	48.0	61.5		
	Maximum Operational Flexibility Alternative	19.4	46.8	83.3	126.8	158.5	174.6	201.0	203.4	203.4	203.4
	Supply Driven (LB Priority Approach) Alternative	19.4	46.8	83.3	126.8	158.5	174.6				
	Supply Driven (LB Pro Rata Approach) Alternative	25.3	36.8	50.5	55.5	58.9	60.6				
	Representative Preferred (2027-2028) Alternative[3]	19.4	46.8	83.3	126.8	158.5	174.6	201.0	203.4	203.4	
	Representative Preferred (2029-2060) Alternative[4]	34.8	85.8	162.2	202.6	203.4	203.4	203.4	203.4	203.4	
Arizona, Tribal Agriculture, Priority 3	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	1.8	3.1	4.6	5.5	6.1	6.4	7.0	9.2		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	13.3	19.2
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	3.6	5.3	7.4	8.2	8.8	9.0				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	13.3	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.7	2.6	9.3	16.6	
Arizona, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	6.8	11.4	17.1	20.5	22.6	23.6	25.9	34.0		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	13.4	19.7	27.4	30.4	32.4	33.4				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
California, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	8.1	9.4	11.0	12.0	12.6	13.0	13.6	15.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	4.2	7.8	9.1	10.1	10.8	11.2				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nevada, Tribal Agriculture, PPR	CCS Comparative Baseline[1]	0.0	0.0								
	No Action Alternative	0.0									
	Basic Coordination Alternative[2]	0.0	0.0	0.0							
	Enhanced Coordination Alternative	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.9		
	Maximum Operational Flexibility Alternative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply Driven (LB Priority Approach) Alternative	0.0	0.0	0.0	0.0	0.0	0.0				
	Supply Driven (LB Pro Rata Approach) Alternative	0.2	0.3	0.4	0.5	0.6	0.6				
	Representative Preferred (2027-2028) Alternative[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Representative Preferred (2029-2060) Alternative[4]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: IMPLAN 2025

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for CCS Comparative Baseline, shortages for 600K and 1,000K are actually associated with 613K and 1,013K in CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf; however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029 – 2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029-2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

In addition to the impacts on jobs, labor income, and economic output presented above, reductions in irrigation water would also lead to impacts on economic conditions through increased costs incurred when fallowing lands, increased strain on farmers' ability to pay fixed costs, and reduced national supply of agricultural crops produced in the analysis area. An increase in fallowing lands would lead to an increase in costs associated with maintaining the fallowed lands, such as costs for controlling and mitigating weeds, pests, and wind erosion. After fallowing lands, there would be additional costs to prepare and return the land to farming crops, such as costs to repair and reestablish irrigation ditches and infrastructure, especially after multiple years of continued fallowing. Farmers could also face financial strains from the reduced revenue associated with increased fallowing lands, if the revenue farmers receive for crop production no longer covers the fixed costs needed to continue and maintain operations. Additionally, increases in fallowed lands could impact the national supply of crops that are largely produced in the analysis area. For example, Arizona is the largest supplier of leafy greens in the U.S. during winter months, and in 2024, Arizona produced over 20 percent of the U.S. lettuce supply throughout the year (Arizona Farm Bureau 2026, USDA NASS 2025, Duval et al. 2024). An increase in fallowed lands due to a reduction in water for irrigation would lead to a reduction in supply of these crops throughout the U.S., which could lead to reduced availability and a potential increase in prices that consumers face for the produce. The magnitude of these impacts depends on several economic and market factors that are outside of the scope of this EIS. The alternatives with the greatest and smallest impacts on the economic conditions discussed above are the same as those discussed for impacts on fallowed lands.

The analysis on economic contributions provides estimated impacts per year of shortage. If shortages continue over multiple years, there will continue to be impacts on economic conditions, including reductions in jobs, labor income, and economic output. Depending on the magnitude of the water delivery shortages each year and the number of years of shortage, impacts on economic contributions could lead to farms ceasing operations permanently, especially for small farmers with limited resources for withstanding multiple years of fallowed lands. If farms cease operating, there could be large, cascading impacts throughout the local and regional economies, especially in regions that heavily rely on agriculture to support livelihoods and well-being throughout the communities. For more information on long-term impacts on changing land use and water deliveries due to water shortages to irrigation entitlement holders, see **TA 4**, Water Deliveries, and **TA 17**, Population and Land Use.

Long-term and deep Colorado River water shortages could result in further impacts on the economic contributions to entitlement holders that have unused water entitlement above their current consumptive use. As discussed in the *Methodology* section above, as well as in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, the analysis of impacts on economic conditions due to changes in agriculture in this EIS is based on modeled shortage volumes to irrigation entitlement holders in terms of consumptive use shortage relative to the consumptive use (or modeled equivalent) entitlement, in order to allow for comparison across the alternatives and shortage distribution methods. On average, from 2019 to 2023, consumptive use was estimated at 87 percent and 85 percent of the consumptive use (or equivalent) entitlements of non-tribal irrigation entitlement holders in Arizona and California, respectively. Consumptive use as a percentage of the consumptive use (or equivalent) entitlements was considerably less for tribal irrigation entitlement holders across the analysis area, with consumptive use making up

approximately 66 percent of the consumptive use (or equivalent) entitlements for tribal irrigation entitlement holders, on average, across Arizona, California, and Nevada (Reclamation 2019, 2020, 2021, 2022, 2023). Irrigation entitlement holders who currently use less than their entitlement (measured in terms of diversion, consumptive use, or both) might not immediately experience impacts on economic contributions from water shortages; however, long-term, continued shortages would limit future opportunities to expand the irrigation entitlement holders' water use, which would result in impacts on economic contributions through reduced opportunities for future development, expansion of crop production, or additional opportunities to lease water.

The analysis of impacts on economic conditions discussed above examines the impacts of shortages on agriculture entitlement holders. If there is not enough water in Lake Mead to fully meet downstream demands and/or if Hoover Dam infrastructure constraints result in releases below the demand volume, other measures would be taken in the Lower Basin, such as water conservation or dead pool–related reductions. During some instances of dead pool–related reductions, these unplanned reductions occur because Lake Mead is approaching dead pool (elevation 895 feet) and in some cases it occurs earlier (up to elevation 950 feet). If there are dead pool–related reductions, the impacts on acreages fallowed would likely extend to more high-valued crops as well as result in entire crops or all croplands in certain counties being fallowed. Increases in fallowed lands of these high-valued types of crops would likely lead to greater and longer-term effects on the production value as well as the jobs, labor income and economic output associated with the loss of crop production. The magnitude of these impacts depends on many factors, including the water distribution methods and conservation measures that are implemented; the approach to distributing reductions associated with dead pool is not addressed in this analysis. See the subsection *Shortage vs. Dead Pool–Related Reductions: Comparison for Full Lower Basin,* under **TA 4**, Water Deliveries, for a discussion on the relationship between shortages and dead pool–related reductions for water deliveries across all entitlement holders.

In addition to impacts on economic conditions, increases in water shortages would likely lead to changes in quality and access to nonmarket values and social conditions associated with changes in agriculture. As more land is fallowed due to shortages in water delivered from the Colorado River, the livelihoods, the way of life, and the health of individuals throughout the surrounding communities could change, which can impact how the individuals perceive their sense of place and interact with the local communities, land, and individuals around them. Many communities, especially tribes in the surrounding regions, value the use of Colorado River water for irrigation for the food that it supports as well as for access to cultural, traditional, and spiritual purposes, and impacts on agriculture can greatly reduce access to and quality of these values (Curtis et al. 2023). Additionally, impacts on agriculture due to water shortages can affect the well-being of communities through effects on access to affordable health and dental care and funding to support public services such as education, especially for tribes and farmers who rely on agricultural revenues to pay for healthcare and for communities that rely on agriculture to support the economy and public services. Increases in fallowed agricultural lands could be a source of fugitive dust, particularly under dry and unvegetated conditions, which could also impact the well-being and quality of life for communities in the analysis area (for more detail on impacts on fugitive dust emission, see **TA 7**, Air Quality). Fallowing of land with fruit or nut trees would lead to reduced sources of shade, which could result in impacts on quality of life of neighboring communities through urban heat impacts (such as heat

related illness; see **TA 17**, Population and Land Use, for more information on impacts to communities related to loss of urban and suburban trees due to reductions in domestic water). The alternatives with the greatest and smallest impacts on social conditions and access and quality of nonmarket values are the same as those discussed for impacts on fallowed lands. On average, for non-tribal entitlement holders in Arizona and California, when the total shortages are less than or equal to 3.0 maf, the greatest impacts on social conditions and access and quality of nonmarket values associated with agriculture are likely to occur under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives; with shortages greater than 3.0 maf, the greatest impacts on social conditions and nonmarket values due to changes in agriculture are likely to occur under the Maximum Operational Flexibility, Enhanced Coordination, and Representative Preferred (2029-2060) Alternatives, for non-tribal agriculture entitlement holders in Arizona and California. On average, for Arizona tribal entitlement holders, during shortages of 0.6 maf, impacts on social conditions and access to and quality of nonmarket values associated with agriculture would be the greatest under the Supply Driven Alternative (LB Pro Rata approach); with shortages greater than 0.6 maf but not more than 2.0 maf, impacts on social conditions and access to and quality of nonmarket values would be greatest under the Basic Coordination and Representative Preferred (2029-2060) Alternatives; with shortages greater than 2.0 maf, impacts on social conditions and access and quality of nonmarket values would be the biggest under the Maximum Operational Flexibility and Representative Preferred (2029-2060) Alternatives. For California and Nevada tribal entitlement holders, impacts on social conditions and access and quality of nonmarket values would be greatest under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, and there would be little to no impacts on social conditions and access and quality of nonmarket values under all other alternatives and the CCS Comparative Baseline. For more information on the impacts on tribal interests and tribal entitlement holders, see **TA 13**, Tribal Resources, and **TA 18**, Indian Trust Assets.

As discussed above in the *Assumptions* subsection, under *Agriculture*, the analysis of impacts on economic and social conditions due to changes in agriculture assumes that water shortages would lead to an increase in fallowed lands rather than a change in water sources—for example, a switch to use groundwater or other surface water sources for irrigation. If other surface water or groundwater sources are used instead of fallowing agriculture acreages, the impacts on economic and social conditions due to lost agriculture production are likely to be lessened, at least in the short term. However, the reliance on more pumped groundwater to offset delivery shortages can lead to substantial additional pumping costs, particularly for electricity (for an analysis of impacts on hydropower, including impacts on energy generation, refer to **TA 15**, Dams and Electrical Power Resources). The magnitude of the increase in costs due to pumping groundwater depends on several factors including the proximity of the agriculture land to the Colorado River. If there are large increases in cost for agriculture production—for example, on land near the Colorado River and for farmers who previously had low costs for Colorado River water delivery—the increase in cost would lead to reduced profitability of crops and could lead to an increase in fallowed lands and reduced agriculture production, especially for small farmers who are not able to absorb higher operating costs or who produce low-profitable or water-intensive crops. Additionally, in the long term, if water delivery shortages continue over multiple years and there is more sustained reliance on groundwater for irrigation, resulting in the depletion of aquifers, the water supply of both groundwater as well as the surface water from the Colorado River could reduce, which would likely lead to greater levels of

fallowed lands, a decrease in market value of crops produced, and a reduction in jobs, labor income, and economic output. A greater demand for groundwater could also lead to impacts on users and tribes who rely on groundwater for irrigation and domestic needs, similar to those impacts on economic and social conditions discussed above.

TA 16.2.3 Issue 2: How would operational changes affect economic contributions and the value associated with lake-based and river-based recreation?

The economic contribution analysis is presented below in **Table TA 16-25** for lake-based recreation and **Table TA 16-26** for river-based recreation for the CCS Comparative Baseline. A qualitative analysis is provided by action alternative based on potential changes to recreational visitation data.

Table TA 16-25
Economic Contributions- Lake-Based Recreation — CCS Comparative Baseline, 2025$

	Employment (jobs)	Output ($)	Labor Income ($)
Glen Canyon Totals	**3,697**	**484,052,913**	**164,064,861**
Direct	2,878	343,102,820	119,990,451
Indirect	412	68,662,216	22,184,610
Induced	407	72,287,877	21,889,800
Lake Mead Totals	**1,768**	**266,778,297**	**93,043,949**
Direct	1,223	159,360,100	59,751,812
Indirect	243	50,135,433	15,668,510
Induced	302	57,282,764	17,623,628

Source: IMPLAN 2025

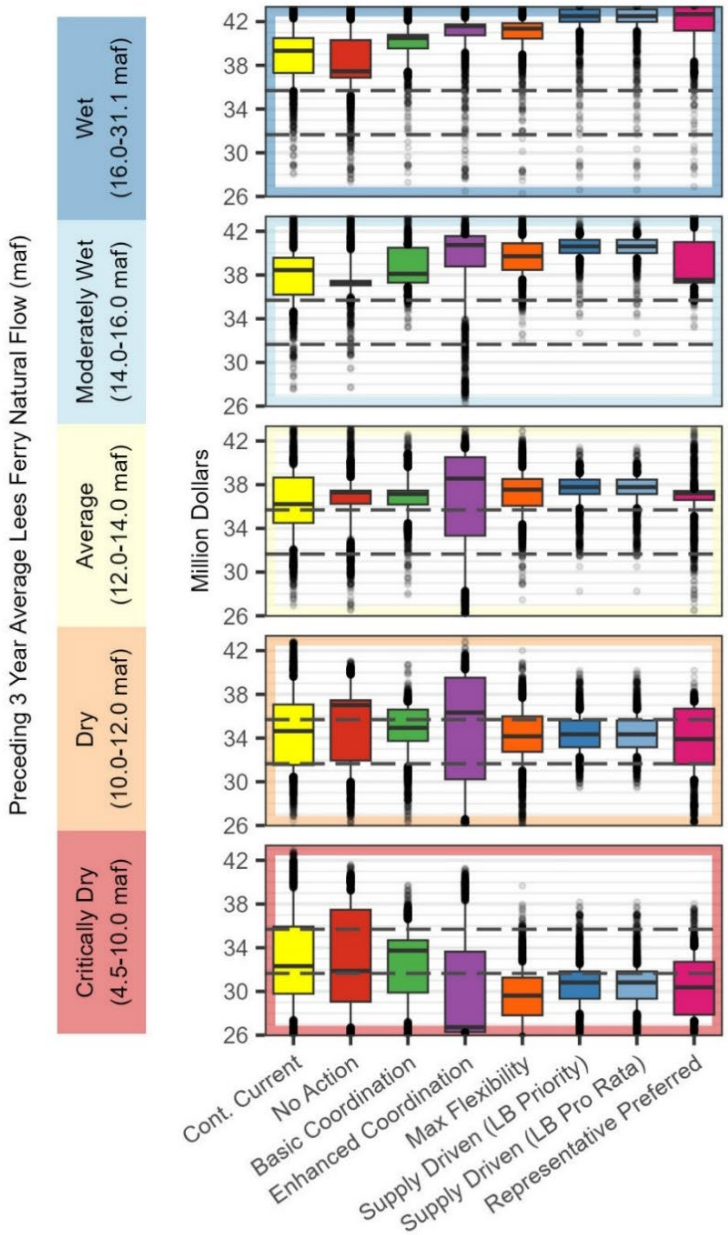
Table TA 16-26
Economic Contributions- River-Based Recreation — CCS Comparative Baseline, 2025$

	Employment (jobs)	Output ($)	Labor Income ($)
Grand Canyon Totals	**6,805**	**846,100,020**	**163,163,321**
Direct	5,301	584,485,312	119,097,734
Indirect	765	129,646,343	22,299,651
Induced	740	131,968,365	21,765,936

Source: IMPLAN 2025

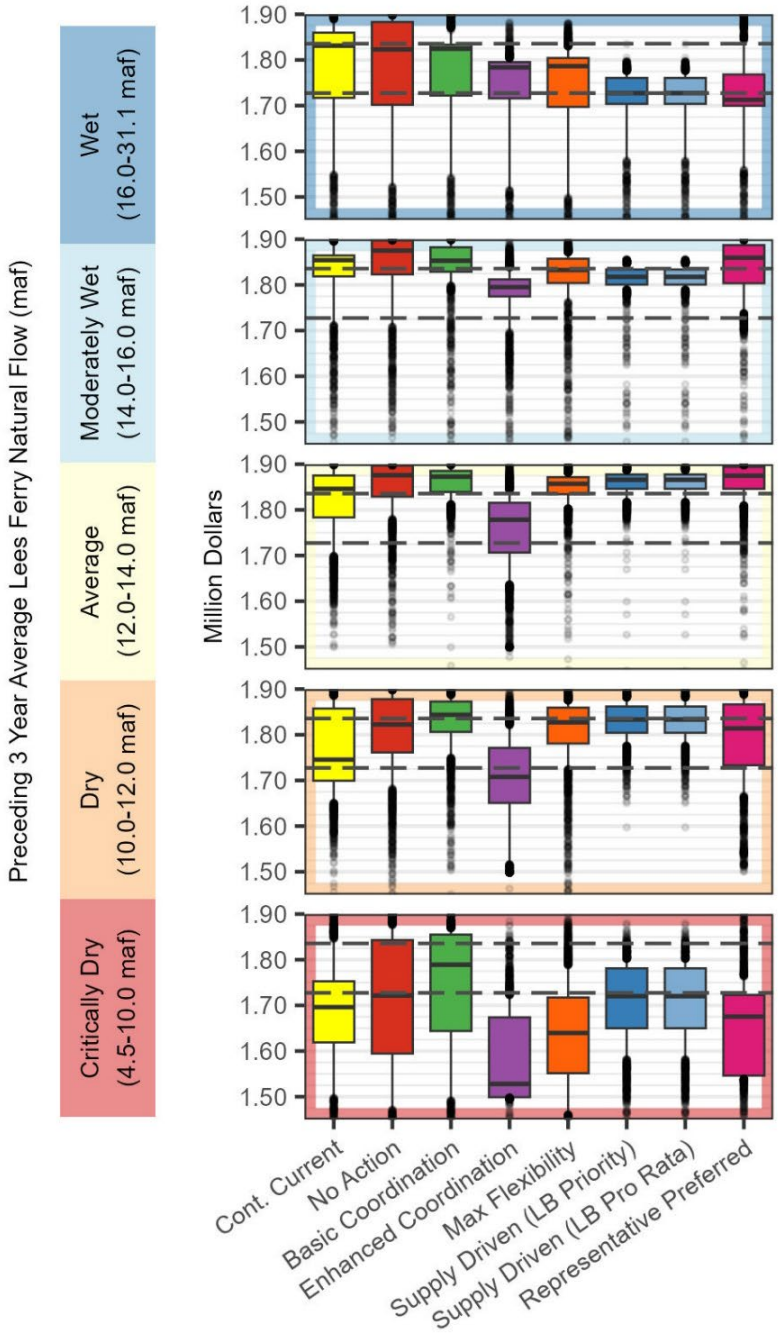
Figure TA 16-11 and **Figure TA 16-12** illustrate how the different Post-2026 operational alternatives perform in maintaining angling and boating recreational value across a wide range of plausible future hydrologic conditions. For whitewater boating, the lower reference line ($31.65 million of annual value) represents a "bad year" for economic value of whitewater rafting. It is calculated by modeling CCS Comparative Baseline in 2000–2023 hydrology and taking the

Figure TA 16-11
Annual Value of Whitewater Rafting Conditional Box Plot (2025 dollars)



Source: Bair 2026

Figure TA 16-12
Annual Value of Angling Conditional Box Plot (2025 dollars)

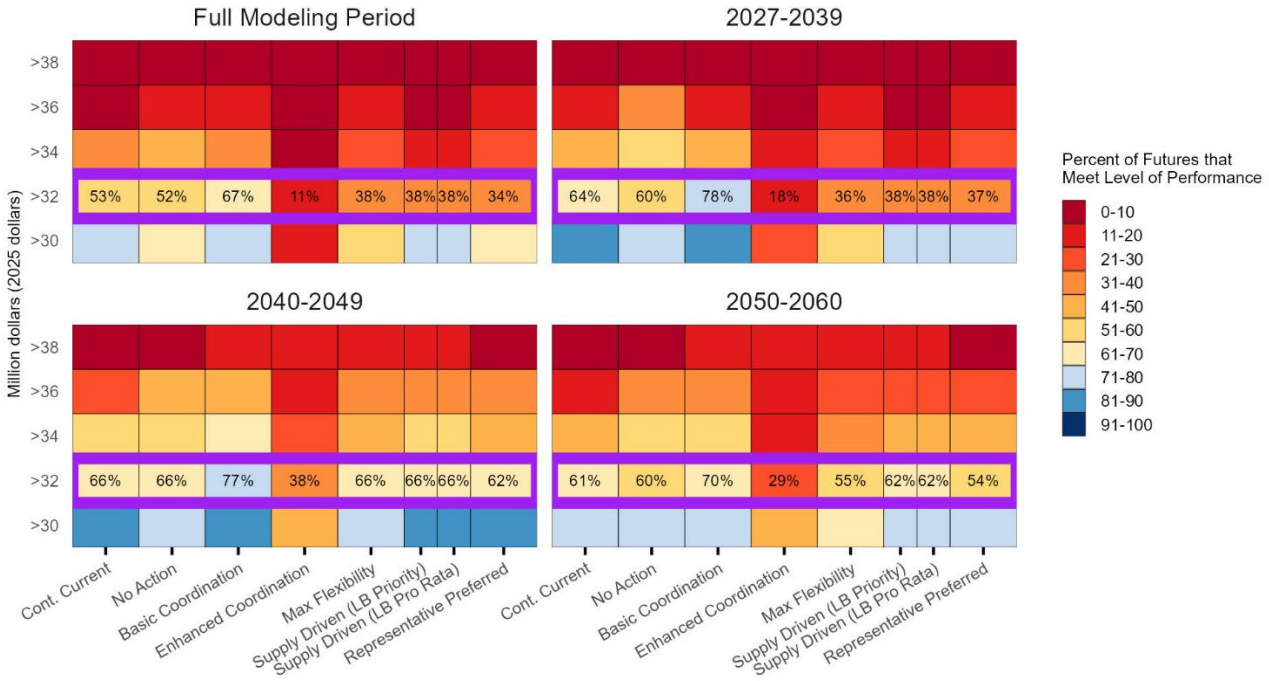


Source: Bair 2026

10th percentile (that is, only 10 percent of years resulted in less than or equal to a value of $31.65 million). The upper reference line ($35.69 million) represents a "normal year" and is calculated as the 50th percentile of CCS Comparative Baseline tested in the 2000–2023 hydrology. The same approach is taken for angling values, with the lower reference line (lowest 10th percentile) of $1.73 million representing poor past performance and $1.84 million (50th percentile) for the upper reference line of a "normal" year (Bair 2026). Below these levels, impacts on overall recreational values from these uses would be anticipated. It should be noted that the conditional box plots for all alternative exhibit a high range of variability of data, particularly in the case of angling value, with outliers at the high and low ends of the economic value output. As a result, the alternative comparison below focuses primarily on median and the interquartile range.

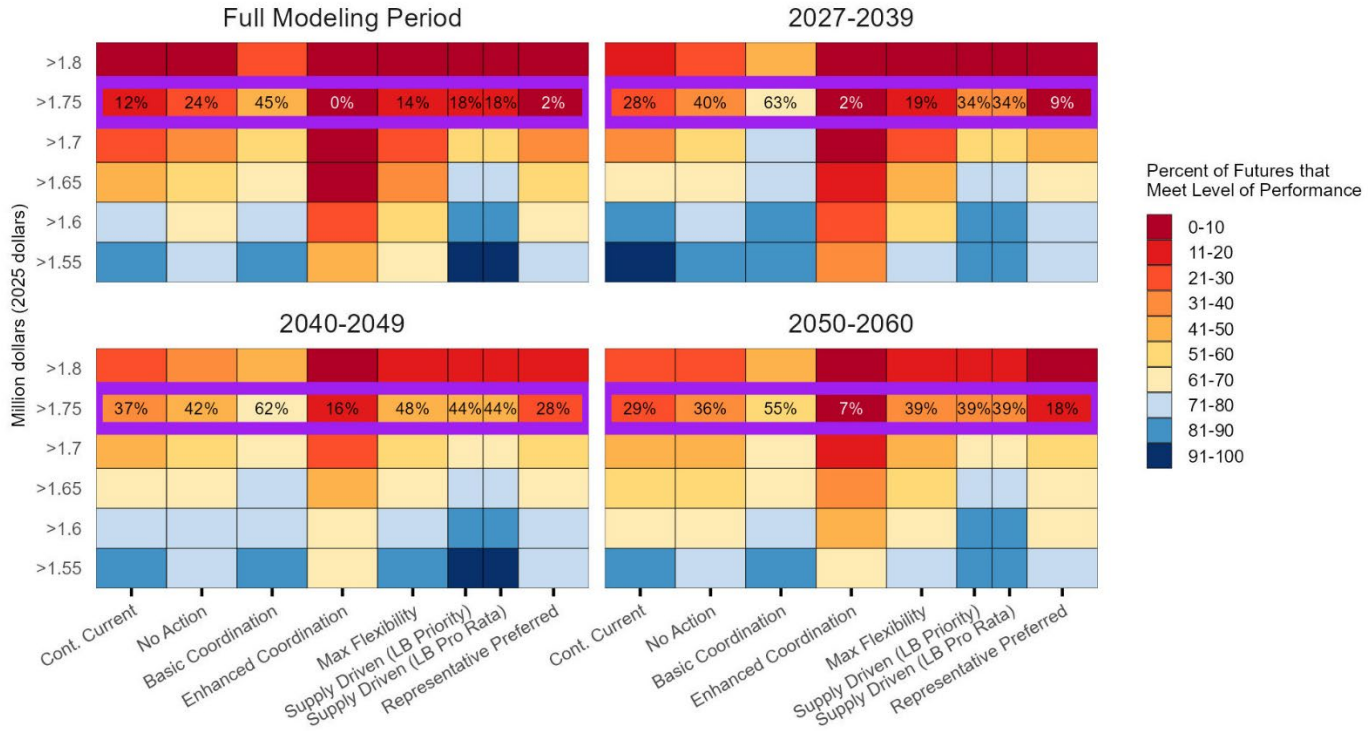
Figure TA 16-13 and **Figure TA 16-14** carry forward the minimum performance threshold representing the worst 10 percent of recreational value outcomes (that is, $32 million for whitewater boating and $1.8 million for angling), as indicated in the purple highlighted row. These figures show a heatmap for the complete modeling period, with a summary in the graph in the upper left of the figure, with the percentage of futures indicated which meet the specified level of performance for at least 90 percent of years.

Figure TA 16-13
Whitewater Boating Economic Value: Robustness.
Percent of futures in which the annual value of whitewater boating exceeds the value specified in each row in at least 90 percent of years



Source: Bair 2026

Figure TA 16-14
Angling Economic Value: Robustness.
Percent of futures in which the annual value of angling exceeds the value specified in each row in at least 90 percent of years



Source: Bair 2026

Operational changes influence recreation primarily through their effects on reservoir elevations and river flows, which in turn shape visitor access, trip quality, and spending patterns. The following discussion examines how these dynamics affect economic contributions and recreational value across lake-based and river-based settings. Summary information is included below for summer recreation site access in both Lake Mead and Lake Powell, as well as thresholds for navigation for both reservoirs. In addition, ability to maintain flow levels to support commercial whitewater rafting is examined. More details, including additional recreation thresholds, are examined in **TA 14**, Recreation.

For lake-based recreation, under the CCS Comparative Baseline, recreation-related economic contributions are shaped by projected reservoir conditions that affect access and participation. Across the full modeling period, and the 2027–2039 subperiod none of the alternatives or the CCS Comparative Baseline would maintain at least 60 percent of Lake Powell recreational sites open during the summer months at Lake Powell. These results translate to widespread closures of Lake Powell recreation sites and boat launch ramps over the next decade and potential for reduced economic contributions (see **Figure TA 14-1** in **TA 14**, Recreation). In terms of navigation, the CCS Comparative Baseline would be slightly less robust than the No Action Alternative, with 49 percent and 58 percent of futures, respectively, over the full analysis period and 42 and 47 percent

respectively over the first decadal period meeting the threshold of 3,620 feet, which corresponds to the critical threshold navigation in Lake Powell (see **Figure 14-3** in **TA 14**, Recreation).

Similarly, for Lake Mead all alternatives exhibit poor performance at maintaining at least 80 percent of Lake Mead recreational sites open during the summer months, indicating that widespread reductions in recreation site availability are likely under a broad range of future conditions, with potential for reduced economic contributions as a result. (**TA 14**, Recreation). The No Action Alternative would support recreation access in 2 percent of futures while the CCS Comparative Baseline was successful in 7 percent of futures over the full modeling period (3 and 12 percent over the first decadal period respectively). In terms of critical thresholds for navigation, the CCS Comparative Baseline would be similar to the No Action Alternative, with 27 percent and 28 percent of futures, respectively, over the full analysis period and only 13 and 12 percent over the first decadal period meeting the critical threshold for navigation (see **TA 14**, Recreation).

IMPLAN results for the CCS Comparative Baseline (**Table TA 16-25**) show current recreational activity supports approximately 3,697 jobs and $484.1 million in output related to recreation at Glen Canyon NRA, and 1,768 jobs and $266.8 million related to recreation at Lake Mead NRA. These totals reflect direct visitor spending and the indirect and induced effects that ripple through gateway economies. The CCS Comparative Baseline serves as the benchmark for comparing the action alternatives' potential impacts on recreation-related employment and economic activity.

As described in **TA 14**, Recreation (**Figures TA 14-1** and **14-2**), Lake Powell elevations for much of the analysis period are expected to remain below critical thresholds for some launch facilities and navigational routes across all alternatives, resulting in reduced reservoir boating opportunities. Lake Mead faces similar challenges across all alternatives in maintaining elevations above navigational hazard thresholds (**Figures TA 14-3** and **14-4**). These access limitations are expected to suppress lake-based recreational spending. Research supports the link between lake levels and recreational spending and employment. Water-based recreation represents a large share of visitor activity at Lake Powell, with 46 percent of visitors participating in motorized boating (NPS 2018). Studies have found lake volume to be a predictor of visitation and spending: a 100 thousand acre feet (kaf) increase in Lake Powell volume was associated with 5,280 additional visits and $374,000 in spending in Coconino County (Nehr et al. 2013). Duvel et al. (2022), found that reservoir elevation for Lake Powell had a positive, statistically significant effect on total monthly recreational visits, and a negative correlation with unemployment. Conversely, reductions in elevation from 3,675 to 3,625 feet were estimated to result in more than a 25 percent decline in visitation (Johnson et al. 2016). Similar patterns are expected at Lake Mead, where low water levels would render most boat launches inaccessible and increase navigational hazards, reducing visitor experience and spending (Reclamation 2024), although some studies suggest this relationship may be less robust than that in Lake Powell. Reservoir elevation was estimated to have a positive, but not statistically significant effect on total monthly recreational visitors in a study by Duval et al. (2022). These changes could affect concessionaire viability and reduce revenue streams for gateway businesses reliant on extended recreational seasons (Reclamation 2024). These impacts include potential impacts on tribal concessionaries as discussed in **Section TA 16.1.3** and **TA 18**, Indian Trust Assets.

River-based recreation, including angling in Glen Canyon and whitewater rafting in Grand Canyon, is sensitive to flow conditions below Glen Canyon Dam. As noted in **TA 14**, Recreation, flows below 10,000 cubic feet per second (cfs) and above 45,000 cfs are considered less than optimal for rafting, while flows between 20,000 and 26,000 cfs are optimal. Commercial guides identify 8,000–9,000 cfs as the minimum level necessary for safe trips. Analysis for impacts of proposed management on flow indicates that the No Action Alternative is slightly less robust than the CCS Comparative Baseline at maintaining daytime flows of at least 8,000 cfs, with 67 percent of futures across the full modeling period meeting defined thresholds under the No Action Alternative compared to 58 percent under the CCS Comparative Baseline (75 percent and 55 percent when the first decadal period is examined) . This suggests the No Action Alternative may provide less consistent support for preferred rafting conditions than current conditions (see **Table TA 14-5** in **TA 14**, Recreation). Variability in flows could influence trip quality and safety, which in turn affects both the value associated with the recreational experience and economic contributions from commercial river trips and related services in gateway communities.

IMPLAN output for CCS Comparative Baseline for GCNP estimates support for 6,805 jobs and $846.1 million. As for lake-based recreation, these totals reflect direct visitor spending and the indirect and induced effects that ripple through gateway economies.

The CCS Comparative Baseline and the No Action Alternative are successful at keeping both whitewater boating values above determined thresholds feet 90 percent of the time in 53 percent and 52 percent of futures, respectively. When just the first decadal modeling period is examined, these values are slightly improved at 64 percent of futures for CCS and 60 percent for the No Action Alternative. For angling, the CCS Comparative Baseline and the No Action Alternative are successful at keeping values above determined thresholds in 12 percent and 24 percent of traces respectively. When just the first decadal modeling period is examined, performance is slightly improved, with the CCS has values above determined thresholds in 28 percent of traces and the No Action Alternative has values above thresholds 40 percent. When examining conditional box plots, under wet and moderate hydrologic conditions, all alternatives and the CCS Comparative Baseline maintain recreational value associated with boating and angling above the established critical threshold ranges. Under dry hydrologic conditions, the CCS Comparative Baseline and the No Action Alternative maintain median values within the minimum threshold levels for whitewater boating and angling. Under critically dry conditions, the CCS Comparative Baseline median is below the defined thresholds for angling recreational value; under the No Action Alternative, the median is just above the minimum range. For whitewater boating recreational value, the median is just above the minimum range for both the No Action Alternative and the CCS Comparative Baseline. This data indicates that under the No Action Alternative and the CCS Comparative Baseline, under dry hydrological conditions future recreational values are likely to be maintained but under critically dry conditions impacts may occur.

Under the Basic Coordination Alternative, greater flexibility in releases begins to shift the frequency and duration of low-elevation periods, with implications for both lake access and river flow stability. The Basic Coordination Alternative introduces shortages up to 1.48 maf and allows Lake Powell releases to fall to 7.0 maf in low-storage years. These operational changes increase the frequency and duration of low-elevation conditions at Lake Mead and Lake Powell, reducing marina operability and

shortening boating seasons. As noted previously, summer recreation site access is limited under all alternatives. For Lake Powell, in terms of navigation, the Basic Coordination Alternative is slightly less robust than the CCS Comparative Baseline and slightly more robust than No Action Alternative, with a 55 percent success rate over the full analysis period (50 percent over the first decadal period) (see **TA 14**, Recreation). For Lake Mead, the Basic Coordination Alternative succeeded in only 6 percent of futures for summer recreational site access over the full modeling period and the first decadal period, similar performance to the CCS Comparative Baseline (7 percent) and slightly more robust than the No Action Alternative (2 percent) (see **TA 14**, Recreation). Navigation thresholds were achieved in 35 percent of futures over the full modeling period (19 percent over the first decadal period), more robust than the CCS Comparative Baseline and No Action Alternative. These data indicate that overall economic contributions from reservoir recreational activities may be similar under the Basic Coordination Alternative to the CCS Comparative Baseline and No Action Alternative.

For river-based recreation, the Basic Coordination Alternative has a higher level of robustness for whitewater boating value as compared to the No Action Alternative (67 percent of futures having a value above the defined threshold, with 78 percent above the threshold for the first decadal period). This is the most robust of any alternative. Similarly, for angling recreational value, the Basic Coordination Alternative is more robust than any other alternative, with 45 percent of futures maintaining values above the defined threshold for 90 percent of modeled years compared to 24 percent in the No Action Alternative (for the first decadal period performance under the Basic Coordination Alternative is further improved at 63 percent of traces). When examining conditional box plots, under dry hydrologic conditions, for whitewater boating the Basic Coordination Alternative performs slightly worse than the No Action Alternative, with the median just below the identified upper critical threshold; however, there is less variability in the range of outcomes under this alternative. For angling, the Basic Coordination Alternative performs the best of all Alternatives under dry hydrologic conditions, with the median just above the identified threshold range. DMDU analysis performed in **TA 14**, Recreation (**Figure TA 14-5**) also indicates that the Basic Coordination Alternative performs more robustly than the No Action Alternative in maintaining daytime flows of at least 8,000 cfs, which are considered minimally adequate for rafting (80 percent of futures over the full modeling period and 90 percent of futures over the first decadal period), supporting continued or increased economic contributions from commercial river trips over the full modeling period.

For reservoir-based recreation, the Enhanced Coordination Alternative introduces proactive storage balancing and shortages up to 3.0 maf. This alternative is among the most robust in terms of meeting thresholds navigation in Lake Powell (82 percent of futures over the full modeling period and 64 percent over the first decadal period) (see **TA 14**, Recreation). Consequently, economic contributions from lake-based recreation would likely be higher than the CCS Comparative Baseline and No Action Alternative. For Lake Mead, analysis indicates that summer recreational site access thresholds would be achieved in only 4 percent of futures over the full modeling period (5 percent over the first decadal period), and navigation thresholds achieved in 55 percent of futures over the full modeling period (32 percent over the first decadal period). This performance is more robust than both the CCS Comparative Baseline and No Action Alternative for navigation but less robust than CCS Comparative Baseline for recreation site access. As noted above, as under all alternatives,

however, access to launch facilities and safe navigation routes for Lake Powell and navigational challenges in Lake Mead would continue to impact lake-based recreational opportunities and the associated spending, though storage balancing may help limit the duration of extreme low-elevation periods compared to the other action alternatives.

For river-based recreation, the Enhanced Coordination Alternative would be the least robust in maintaining or exceeding minimum desired daytime flows to support boating in Grand Canyon (only 8 percent of futures would meet the defined threshold over the full modeling period and one percent of the first decadal period; **Figure TA 14-5** in **TA 14**, Recreation). DMDU modeling output for angling and boating value aligns with these findings, with whitewater boating and angling values having the least robust performance of all alternatives, with only 11 percent and 0 percent of futures meeting or exceeding defined thresholds for recreational value for boating and angling respectively (18 percent and 2 percent for the first decadal period for boating and angling respectively). When examining conditional box plots, under dry hydrologic conditions, this is the worst performing alternative for angling, with the median falling below the identified minimum threshold. For the recreational value associated with whitewater boating, the median value is slightly below the median seen in the No Action Alternative, but still above the critical thresholds, and higher than other action alternatives. However, this alternative has the widest range for potential outcomes under dry conditions. As a result, this alternative would result in the greatest potential for a reduction in recreational value for angling as well as the associated regional economic contributions associated with this use, and would have an unpredictable level of reduction in economic contributions from whitewater boating.

The Maximum Operational Flexibility Alternative allows shortages up to 4.0 maf and Lake Powell releases as low as 5.0 maf. For river-based recreation, in terms of flow conditions, daytime flows below Glen Canyon Dam under this alternative are more volatile than under the CCS Comparative Baseline and No Action Alternative, increasing the likelihood of extended periods below 8,000 cfs and even near 5,000 cfs, which are considered adverse for rafting (31 percent of futures would meet threshold conditions over the full modeling period and 22 percent over the first decadal period) (see **Figure TA 14-2** in **TA 14**, Recreation). These conditions would diminish trip quality and safety, reducing long-run economic contributions from river-based recreation and nonmarket values tied to scenic quality and experience as compared to the CCS Comparative Baseline and No Action Alternative. DMDU modeling output for angling indicates that the Maximum Operational Flexibility Alternative is slightly more robust than the CCS Comparative baseline but less robust than the No Action Alternative for angling, with 14 percent of futures meeting the minimum defined thresholds over the full modeling period. When only the first decadal period is examined, however, the Maximum Operational Flexibility Alternative is less robust than both the CCS Comparative Baseline and the No Action Alternative for angling (19 percent of futures meeting defined thresholds compared with 28 percent under the No Action Alternative). For whitewater boating, the Maximum Operational Flexibility Alternative is consistently less robust than the No Action Alternative and CCS Comparative Baseline, with 38 percent of futures over the full modeling period meeting or exceeding the defined threshold for recreational value (36 percent in the first decadal period). When examining conditional box plots, under dry hydrologic conditions, for angling value the Maximum Operational Flexibility Alternative performs similar to the No Action Alternative and better than the CCS Comparative Baseline. For whitewater boating the Maximum Operational Flexibility

Alternative performs worse than the No Action Alternative and similar to the CCS Comparative Baseline.

In terms of reservoir elevations, **TA 14**, Recreation, indicates that under the Maximum Operational Flexibility Alternative, maintenance of critical thresholds for navigation in Lake Powell is among the most robust alternatives, with access maintained in 80 percent of futures over the full modeling period (69 percent over the first decadal period). For Lake Mead, recreation access and navigation are similarly more robust than the No Action Alternative and the CCS Comparative Baseline (64 percent over the full modeling period and 36 percent over the first decadal period). As discussed under for the Maximum Operational Flexibility Alternative, consequently, economic contributions from lake-based recreation would likely be higher than the CCS Comparative Baseline and No Action Alternative. Under all alternatives, however, access to launch facilities and safe navigation routes for Lake Powell and navigational challenges in Lake Mead would continue to impact lake-based recreational opportunities and the associated spending.

The Supply Driven Alternative ties Powell releases to a percentage of 3-year average natural flow and applies Mead shortage tiers up to 2.1 maf. Within this framework, two approaches for the Supply Driven Alternative were considered: a Pro Rata approach, which distributes available Colorado River water supplies proportionally across entitlement holders, and a Priority approach, which distributes available Colorado River water supplies in accordance with statutes, case law, and contracts. For reservoir-based recreation, for Lake Powell both the Priority and Pro Rata approaches would be less robust in terms of maintenance of critical thresholds for navigation than the No Action Alternative and the CCS Comparative Baseline which could further impact recreational spending and gateway businesses and concessionaire associated with Lake Powell. In contrast, for Lake Mead, the Supply Driven Alternative modeling represents the most robust outcomes for recreational site access and navigation, supporting continued or increased spending associated with recreational activities for this reservoir.

For river-based recreation, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) is the most robust at maintaining or exceeding daytime flows of 8,000 cfs below Glen Canyon Dam over the full modeling period and among the most robust over the first decadal period, providing the strongest support for maintained or improved recreational value for boating and angling, and economic contributions associated with river-based recreation. DMDU modeling output for angling indicates that the Supply Driven Alternative (both the LB Priority and Pro Rata approaches) are slightly more robust than the CCS Comparative Baseline and less robust than the No Action Alternative, with 18 percent of futures meeting the minimum defined thresholds for 90 percent of future years over the full modeling period (34 percent when just the first decadal period is examined). For whitewater boating the Supply Driven Alternative is less robust than both the CCS Comparative Baseline and the No Action Alternative, with 38 percent of futures meeting or exceeding the defined threshold for recreational value (under both the LB Priority and Pro Rata approaches). When examining conditional box plots, under dry hydrologic conditions, for angling value both the LB Priority and Pro Rata perform similarly to the No Action Alternative and better than the CCS Comparative Baseline, with the median values slightly below that of the No Action Alternative, although there is a smaller range of variability in the Supply Driven Alternative. For whitewater boating value both the LB Priority and Pro Rata perform similarly to the CCS

Comparative Baseline and slightly worse than the No Action Alternative. As for angling recreational value, modeling indicates a smaller range of variability in the Supply Driven Alternative.

As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative Preferred Alternative which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval. While some impacts are influenced by how the Representative Preferred Alternative distributes Lower Basin shortages in 2027-2028 vs. 2029-2060, issue is either minimally sensitive or not sensitive to this distinction, so the different time periods are not discussed.

For reservoir-based recreation on Lake Powell, the Representative Preferred Alternative would be slightly more robust in terms of maintenance of critical thresholds for navigation than the No Action Alternative and CCS Comparative Baseline over both the full modeling period (61 percent of futures above defined thresholds) and the first decadal period (55 percent above defined thresholds). Compared to other action alternatives, this is better than the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), but less robust than the Enhanced Coordination and Maximum Operational Flexibility Alternatives. For reservoir-based recreation on Lake Mead, the Representative Preferred modeling represents less robust outcomes for recreational site access as compared to the CCS Comparative Baseline but slightly more robust outcomes than the No Action Alternative (6 percent for the full modeling period and 7 percent over the first decadal period above defined thresholds). This is a similar level of performance to the other action alternatives, with only the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) showing a more than 2 percent difference in success rate of meeting defined thresholds. For navigation, the Representative Preferred Alternative is more robust at meeting defined thresholds than both the No Action Alternative and CCS Comparative Baseline (48 percent over the first decadal period and 31 percent over the first decadal period). Compared to other action alternatives, the Representative Preferred is less robust than all but the Basic Coordination Alternative in meeting navigational thresholds for Lake Mead, but the performance is more similar to other alternatives when only the first decadal period is examined. Similar to all alternatives, however, access to launch facilities and safe navigation routes for Lake Powell and navigational challenges in Lake Mead would continue to impact lake-based recreational opportunities and the associated spending.

For river-based recreation, the Representative Preferred Alternative is less robust in terms of maintaining or exceeding daytime flows of 8,000 cfs below Glen Canyon Dam than the No Action Alternative and CCS Comparative Baseline over both the full modeling period (51 percent of futures above defined thresholds) and the first decadal period (60 percent above defined thresholds). Compared to other action alternatives, this is less robust performance than the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, but more robust than the Maximum Flexibility and Enhanced Coordination Alternatives. DMDU modeling output for angling indicates that the Representative Preferred Alternative is less robust than all alternatives other than the Enhanced Coordination Alternative with only 2 percent of modeling futures

exceeding defined thresholds (9 percent over first decadal period). For whitewater boating recreational value performance is also less robust than all alternatives other than the Enhanced Coordination Alternative, although the percent of futures is similar to that in the Supply Driven and Maximum Flexibility Alternatives. When examining conditional box plots, under dry hydrologic conditions, for angling value the Representative Preferred Alternative performs similarly to the No Action Alternative and better than the CCS Comparative Baseline, with the median values slightly below that of the No Action Alternative, although there is a smaller range of variability. For whitewater boating value the Representative Preferred Alternative performs similarly to the CCS Comparative Baseline and slightly worse than the No Action Alternative. As for angling recreational value, modeling indicates a larger range of variability under the Representative Preferred. For both angling and boating, performance is also similar to the Maximum Flexibility Alternative and the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), although the Representative Preferred Alternative has a higher range of variability compared to these alternatives. This data suggests overall river-based recreational outcomes and the associated recreational value and economic contributions are likely to experience a high range of variability, which may impact the ability of local communities and concessionaries to depend on this economic activity.

TA 16.2.4 Issue 3: How would anticipated water shortages and changes in water levels in reservoirs and river segments affect access and quality of nonmarket values?

Nonmarket values with potential to be affected by operations generally encompass cultural identity, recreational quality, aesthetics, and existence values, and may vary based on site-specific conditions, user preferences, and other factors. Values specific to tribes are further explored in **TA 18**, Indian Trust Assets, and **TA 13**, Tribal Resources.

In general, the alternatives that facilitate higher reservoir elevations, and maintain more consistent flows along the Colorado River including through Grand Canyon would result in the reduced impacts on identified nonmarket values. There may be exceptions to this generalization; for example, alternatives which provide better support for river-based recreation and associated values may result in less preferable outcomes for reservoir-based recreation and vice versa.

During wet hydrologic conditions, the range of alternatives would generally produce conditions where lake levels and flows along the Colorado River would result in minimal impacts on nonmarket values. However, this varies by resource. For example, nonmarket values such as scenic integrity, solitude, and cultural connections to the river corridor would be maintained at a level similar to current conditions (**TA 19** Visual Resources). Ecological services, including riparian habitat and wildlife viewing opportunities, remain similar to current conditions (see **TA 8**, Biological Resources – Fish and Other Aquatic Species), and cultural landscapes retain the factors which are associated with nonmarket values (see **TA 11**, Cultural Resources). Recreational experiences for boating, angling, and rafting however, may be impacted under all alternatives in their quality and support for sense of place for gateway communities and visitor, as modeling indicates that periods of reservoir elevations below thresholds for recreation facility access and navigation would be more likely than that under historic conditions.

As conditions become drier, the No Action Alternative and CCS Comparative Baseline would result in the most modeled futures where impacts could occur to resources with nonmarket values. For example, nonmarket values for recreation and ecosystem services could be reduced in instances of prolonged drought, which could reduce shoreline aesthetics and diminish the opportunities for solitude at Lake Powell and Lake Mead over time (see **TA 14**, Recreation). Extended low-flow periods could also impact river-based experiences in Grand Canyon due to changes in setting which could impact perceived naturalness (see **TA 3**, Hydrologic Resources). Cultural and spiritual values tied to iconic landscapes and cultural artifacts could also be affected in low-hydrologic flow periods (see **TA 11**, Cultural Resources). Ecological services such as riparian habitat stability may decline, influencing nonuse values related to wildlife and vegetation communities (see **TA 8**, Biological Resources – Fish and Other Aquatic Species).

Under drier conditions, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would be more robust in terms of the support for some nonmarket values, particularly for values associated with Lake Powell. Reservoir levels which are maintained at thresholds that support access for boating and camping in more modeled futures, support experiential benefits and cultural connections (see **TA 11**, Cultural Resources). The quality of river-based recreation is expected to remain high, due to increased stability with flow-dependent activities (see **TA 14**, Recreation); however, a lower average flow may impact some values. Nonuse values tied to ecosystem services, such as wildlife habitat and riparian vegetation, would also be supported (see **TA 8**, Biological Resources – Fish and Other Aquatic Species). As conditions become drier, Lake Powell and Lake Mead landscape character would be better supported under the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives as compared to the No action Alternative and CCS Comparative Baseline (**TA 19,** Visual Resources).

More frequent reservoir low-elevation conditions could occur in the Basic Coordination Alternative, which could noticeably affect nonmarket values tied to lake-based recreation and scenic quality (see **TA 14**, Recreation) although at a reduced level compared with the No Action Alternative and the CCS Comparative Baseline. Reduced reservoir levels may expose previously submerged areas, altering visual character and diminishing the opportunities for solitude. River-based recreation could experience flow variability that affects trip quality and angling success (see **TA 3**, Hydrologic Resources); however, higher average flows may support some river-based values.

Outcomes produced by the Supply Driven Alternative vary depending on the hydrology and location. In wet years, the nonmarket values remain similar to those under the CCS Comparative Baseline; however, in dry sequences, reduced reservoir elevations and altered flow regimes would diminish the scenic quality and access for boating and angling (see **TA 14**, Recreation), for Lake Powell. For Lake Mead, the Supply Driven Alternative is the most robust for supporting reservoir levels at Lake Mead, which support the nonmarket values. River-based recreation would experience moderate variability in trip quality, while ecosystem services and the associated nonuse values would fluctuate with water availability (see **TA 8**, Biological Resources – Fish and Other Aquatic Species). Cultural and spiritual values tied to river corridors may also be affected during extended drought periods (see **TA 11**, Cultural Resources). Similar to the Basic Coordination Alternative, however, higher average flows may support some river-based values.

As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative Preferred Alternative which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval. While some impacts are influenced by how the Representative Preferred Alternative distributes Lower Basin shortages in 2027-2028 vs. 2029-2060, this issue is either minimally sensitive or not sensitive to this distinction, so the different time periods are not discussed.

The Representative Preferred Alternative generally performs in the middle of the range of alternatives for both Lake Powell and Lake Mead elevations as well as river flow, showing moderate robustness in terms of overall support for recreation associated benefits (**TA 14**, Recreation). Overall, this alternative would provide moderate protection for riverine habitat to support cultural values (see **TA 13**, Tribal).

TA 16.2.5 Summary Comparison of Alternatives

Issue 1: How would anticipated water shortages affect economic contributions and social conditions from agriculture?

The lowest impacts on economic and social conditions from reductions in agricultural production and increases in fallowed lands due to shortages in irrigation water, across all alternatives, states, priority groups, and tribal and non-tribal irrigation entitlement holders, would occur under the No Action Alternative due to the low maximum shortage of 0.6 maf; however, across the action alternatives, impacts on economic and social conditions from changes in agriculture would vary across irrigation priority groups and tribal and non-tribal entitlement holders, based on the maximum shortage levels and water shortage distribution methods.

Under low shortage levels, on average across all priority groups, for all irrigation entitlement holders except Arizona tribal (Arizona non-tribal, California non-tribal, California tribal, and Nevada tribal irrigation entitlement holders), impacts on the economic and social conditions due to reductions in agricultural production would tend to be lower under the alternatives with priority shortage distribution methods (such as under the Basic Coordination, Maximum Operational Flexibility, and Supply Driven [LB Priority approach] Alternatives), and impacts would tend to be higher under the alternatives with pro rata shortage distribution methods (under the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives). In contrast, under low shortage levels, for Arizona tribal irrigation entitlement holders, impacts on the economic and social conditions due to reductions in agricultural production would be similar across all action alternatives. During times of extensive drought, when maximum shortage levels are implemented, on average across all priority groups, for all irrigation entitlement holders except Arizona tribal, impacts on the economic and social conditions from agricultural activity would tend to be lower under the alternatives with a low maximum shortage level and priority shortage distribution methods (such as under the Basic Coordination Alternative), and impacts would tend to be higher under the alternatives with a high maximum shortage level or pro rata shortage distribution methods (such as the Enhanced

Coordination, Maximum Operational Flexibility, or Supply Driven [LB Pro Rata approach] Alternatives), compared with the other action alternatives. However, for Arizona tribal entitlement holders, during times of maximum shortage levels, lower impacts on the economic and social conditions due to reductions in agricultural production would occur under the alternatives with pro rata shortage distribution methods (such as under the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives) and higher impacts would occur under the alternatives with priority shortage distribution methods (such as under the Basic Coordination, Maximum Operational Flexibility, and Supply Driven [LB Priority approach] Alternatives), compared with the other action alternatives. These impacts vary across priority groups. The largest impacts on economic and social conditions during a maximum shortage level, for tribal and non-tribal PPR priority holders, would tend to occur under the action alternatives with a pro rata shortage distribution methods, while the largest impacts for the more junior priority holders (Arizona non-tribal priorities 4(i), and Arizona tribal priorities CAP Indian, 4(i), and 3) would tend to occur under the action alternatives with a priority shortage distribution method and higher maximum shortage level (such as the Maximum Operational Flexibility Alternative). In contrast, the largest impacts for non-tribal and tribal priority group 3 in Arizona and non-tribal priority groups 2 and 3 in California would tend to occur under alternatives with pro rata shortage distribution methods, during periods of low shortages, and would tend to occur under alternatives with a priority shortage distribution method and higher maximum shortage level (such as the Maximum Operational Flexibility Alternative) during period of severe droughts and maximum shortages levels. Overall, the alternatives demonstrate a trade-off between shortage distributions across irrigation entitlement holders, flexibility in the maximum allowable shortage implementation, and the ability to support stable agricultural production and social well-being.

Issue 2: How would operational changes affect economic contributions and value associated with lake-based and river-based recreation?

Recreation-based economies are highly sensitive to changes in reservoir elevations and river flow conditions. Under the alternatives that sustain more stable water levels, boating and shoreline access would remain consistent, supporting steady visitation and related spending that currently contributes about 12,000 jobs and $1.6 billion in output across the Basin.

Operational changes under the proposed alternatives would influence these conditions in different ways. The alternatives that maintain higher and more consistent water levels would preserve boating access, marina operations, and shoreline recreational opportunities. This stability would support continued visitation and minimize disruptions to businesses dependent on tourism. Conversely, the alternatives that result in greater variability in lake elevations and river flows would affect the recreational quality and access and the related levels of contributions.

Under all alternatives, restrictions on summer recreation access and safe navigation routes for Lake Powell and navigational challenges in Lake Mead would continue to impact lake-based recreational opportunities and the associated spending. As a result, outfitters and concessionaires operating in these areas would face increased uncertainty, affecting employment and revenue streams under all alternatives. Research indicates that declines in lake elevation can reduce visitation by more than 25 percent, amplifying economic losses for local communities (Johnson et al. 2016). Lake Mead would experience similar constraints, with boating access severely limited during extended drought periods.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) poses the greatest risk to recreation-based economies relying on economic contributions from reservoir-based recreation in Lake Powell, while the CCS Comparative Baseline and the No Action Alternative have the least robust modeled performance for supporting recreational opportunities and spending associated with Lake Mead recreation. In contrast, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in more consistent reservoir levels at Lake Powell to support recreation, and the Supply Driven Alternative would support the greatest level of contributions from recreation in Lake Mead. Under the Representative Preferred Alternative, support for navigation in Lake Powell would be slightly more robust in terms of maintenance of critical thresholds for navigation than the No Action Alternative and CCS Comparative Baseline. For Lake Mead, the Representative Preferred would be less robust outcomes for recreational site access as compared to the CCS Comparative Baseline but slightly more robust outcomes than the No Action Alternative. For navigation, the Representative Preferred Alternative is more robust at meeting defined thresholds than both the No Action Alternative and CCS Comparative Baseline. Compared to other action alternatives, the Representative Preferred is less robust than all but the Basic Coordination Alternative in meeting navigational thresholds, but the performance is more similar to other alternatives when only the first decadal period is examined.

River-based recreation is also vulnerable to operational changes. Activities such as angling in Glen Canyon and whitewater rafting in Grand Canyon depend on stable flows to ensure safety and trip quality. Reduced flows shorten rafting seasons and diminish the overall experience, leading to lower recreational value and reduced demand for outfitter services and the associated hospitality sectors. The Basic Coordination Alternative would provide the most support for continued or increased economic value associated with boating and angling and related economic contributions. The Enhanced Coordination Alternative would be the least robust at maintaining or exceeding the minimum desired daytime flows to support boating in Grand Canyon; it also would result in the greatest potential for a reduction in recreational value for whitewater rafting and angling as well as the associated regional economic contributions associated with these uses. Impacts would be most pronounced under dry hydrologic conditions.

The Representative Preferred Alternative would provide reduced support for economic contributions from river-based angling and boating compared to most other action alternatives; DMDU modeling output for angling and boating indicates that the Representative Preferred Alternative is less robust than all alternatives other than the Enhanced Coordination Alternative.

Economic impacts extend beyond direct visitor spending. Gateway communities, often small and rural, rely heavily on tourism-related income to sustain local businesses and municipal services. When lake levels drop or river flows decline, these communities experience cascading effects, including reduced tax revenues and job losses in sectors such as lodging, food service, and transportation. The magnitude of these impacts would depend on the frequency and duration of low-elevation conditions, which would vary significantly across the alternatives.

Issue 3: How would anticipated water shortages and changes in water levels in reservoirs and river segments affect access and quality of nonmarket values?

Changes in reservoir elevations and river hydrology also influence nonmarket values such as scenic quality, solitude, and cultural and spiritual connections to the river corridor. More stable operating conditions preserve visual continuity and access to culturally important sites, supporting a sense of place and maintaining the experiential qualities associated with national parks, recreation areas, and other designated lands (see **TA 11**, Cultural Resources). In wet hydrologic conditions, all alternatives support the preservation of conditions which support nonmarket values, although the level of support varies by resource. Under dry hydrologic conditions, however, the No Action Alternative and CCS Comparative Baseline would result in reductions in reservoir levels and greater variability in river flow especially as compared to the Enhanced Coordination and Maximum Operational Flexibility Alternatives. This would result in more frequent exposure of drawdown zones and shifts in shoreline character, diminishing the aesthetic and spiritual values tied to the river's natural appearance. Variability in flows and elevations could also affect the timing and accessibility of traditional practices for tribes and local communities. In general, the alternatives that moderate elevation changes better sustain these nonmarket benefits, while those allowing greater fluctuation introduce tradeoffs between resource protection and system adaptability.

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Technical Appendix 17

Population and Land Use

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
ADM	Alternative Distribution Model
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
Basin	Colorado River Basin
CAP	Central Arizona Project
CCS	Continued Current Strategies
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
ICS	intentionally created surplus
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
maf	million acre-feet
M&I	municipal and industrial
Mexico	United Mexican States
MWD	Metropolitan Water District of Southern California
NIA	non-Indian agriculture
NPS	National Park Service
PPR	present perfected right
SAM	Shortage Allocation Model
SNWA	Southern Nevada Water Authority
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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TA 17. Population and Land Use

This section explores the baseline conditions and potential impacts from different Colorado River operational strategies on analysis area population dynamics and land-use changes, with a focus on potential changes in developed lands and lands used for irrigated agriculture.

Baseline information is provided to characterize the existing setting and trends related to population, general landownership and management, and developed land patterns. Information is also provided for municipal water, which supports developed land use. Data are provided related to historical agricultural land use to support the discussion of irrigated agriculture.

Due to the influence of municipal water availability on developed lands, the impacts analysis examines changes to water availability for municipal supply and the related impacts on population and land-use changes. Due to the influence of irrigation water availability on agricultural land use, the impacts analysis examines changes to irrigation water availability and related impacts on acres of lands in agriculture.

TA 17.1 Affected Environment

The analysis area for the population and land-use section is separated by state and is the same for both population and land-use issues. The impact analysis area is defined by those counties that may be affected by management direction that could result in water shortages to domestic and irrigation users. Because both issue statements rely on the Shortage Allocation Models (SAMs), the analysis area is informed by the SAMs and includes the counties represented in the SAMs. For more detailed information on the SAMs, see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation. For more information on water deliveries, including those for irrigation, refer to **TA 4**, Water Deliveries.

The Arizona analysis area consists of Apache, Coconino, Gila, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, and Yuma Counties. These include counties that are directly adjacent to Lake Powell, Lake Mead, or the Colorado River and counties in which shortages would likely occur.

The California analysis area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. These counties were selected because they are either directly adjacent to the Lower Colorado River, or they are within the Metropolitan Water District of Southern California (MWD) service area. Although Ventura County is also in the MWD service area, it does not receive any water from the Colorado River; therefore, it is not included in the analysis area.

The Nevada analysis area consists of Clark County. The analysis area was limited to Clark County because Clark County is adjacent to Lake Mead and encompasses the Southern Nevada Water

Authority's (SNWA) service area and other individual water providers. Shortages in Nevada would be limited to the SNWA's service area.

The Utah analysis area consists of Kane, Garfield, and San Juan Counties. Although these counties are not in the Lower Colorado River Basin (Lower Basin) and thus would not experience shortages, baseline information on population and land use is included to provide content for analysis of social and economic impacts from recreation associated with the Colorado River, Lake Powell, and Lake Mead (see **TA 16**, Socioeconomics).

Across the states, these counties were selected for inclusion in the analysis area because they represent the counties in which there is potential for direct impacts from shortages, based on modeled domestic (municipal) delivery outcomes and the service areas of major municipal providers. Secondary impacts could also occur in adjacent counties, across states as a whole, in adjacent states, and/or on the national scale (for example, through economic linkages and supply chains). However, due to analytical constraints and the focus of this technical appendix on an assessment of modeled domestic shortage outcomes for selected municipal providers informed by Decision Making under Deep Uncertainty (DMDU), the population and land-use analysis focuses on direct impacts within the counties that correspond to municipal service areas and areas where delivery reductions could most directly influence land-use-related conditions.

This approach is consistent with the socioeconomic framing (**TA 16**, Socioeconomics), which defines the analysis areas using counties adjacent to reservoirs and the Colorado River and counties containing major municipal service areas that receive water from the Colorado River (for example, in California, counties within the MWD service area that receive Colorado River water).

TA 17.1.1 Population

Population trends provide important context for understanding water supply (domestic and irrigation), demand, and use within the analysis area. Although population growth can influence municipal water demand, population is not a direct proxy for consumptive water use because conservation, reuse, demand-management measures, water-use efficiency, local policy, and land-use patterns can affect per-capita demand. As a result, population and water demand may not increase at the same rate. Communities throughout much of the western United States (U.S.) have followed trends of increasing population over the past decade. In the analysis areas, the population growth rate has generally been positive or stable. County- and state-level population changes are discussed below (see **Table TA 17-1** through **Table TA 17-4**).

Arizona

Except La Paz and Apache Counties, which saw a decrease in population (of 18.8 percent and 6.1 percent, respectively), and Navajo County, which maintained its population, all counties in the analysis area followed the trend of increasing population from 2010 to 2022; the biggest increase was in Pinal County (31.6 percent). **Table TA 17-1** provides an overview of populations by county in the Arizona analysis area. Arizona's population is anticipated to continue to increase over the analysis period, with similar county-level trends continuing. Drivers of population increase in Pinal County included low housing costs and workforce increases from new manufacturing, logistical, and distribution facilities (Arizona Office of Economic Opportunity 2024).

Table TA 17-1
Arizona Population 2010–2040

Geographic Area	Population 2010[1]	Population 2022[2]	Percent Change 2010–2022	Estimated Population 2040[3]	Estimated Percent Change 2022–2040
Apache County	70,312	66,054	-6.1	64,449	-2.4
Coconino County	131,824	144,705	9.8	159,557	10.3
Gila County	53,272	53,419	0.3	55,866	4.6
Graham County	36,030	38,453	6.7	44,028	14.5
La Paz County	20,549	16,681	-18.8	16,897	1.3
Maricopa County	3,751,410	4,430,871	18.1	5,762,655	30.1
Mohave County	199,177	214,229	7.6	270,598	26.3
Navajo County	107,060	107,110	0.0	104,100	-2.8
Pima County	964,462	1,042,393	8.1	1,195,070	14.6
Pinal County	329,297	433,338	31.6	778,909	79.7
Yuma County	190,526	204,374	7.3	259,032	26.7
Yavapai County	209,260	237,830	13.7	301,937	27.0
Arizona	6,246,816	7,172,282	14.8	9,206,879	28.4

Sources: U.S. Census Bureau 2012,[1] 2023;[2] Arizona Office of Economic Opportunity 2023[3]

California

In California, the population increased by 7.4 percent from 2010 to 2022. With the exception of Los Angeles, Imperial, and Orange Counties, the analysis area counties' growth all surpassed that of the state. The largest increase in population was in Riverside County (15.2 percent; see **Table TA 17-2**). Historical trends are expected to continue over the next 20 years, with the largest increases forecasted for Imperial and Riverside Counties; notably, a decrease in population of 2.1 percent is anticipated for Los Angeles County. Factors influencing population loss likely include the cost of housing leading to out-migration, as well as other demographic factors such as population aging and low birth rate (Johnson et al. 2023).

Table TA 17-2
California Population 2010–2040

Geographic Area	Population 2010[1]	Population 2022[2]	Percent Change 2010–2022	Estimated Population 2040[3]	Estimated Percent Change 2022–2040
Imperial County	168,052	179,578	6.9	203,470	13.3
Los Angeles County	9,758,256	9,936,690	1.8	9,732,175	-2.1
Orange County	2,965,525	3,175,227	7.1	3,243,240	2.1
Riverside County	2,109,464	2,429,487	15.2	2,703,895	11.3
San Bernardino County	2,005,287	2,180,563	8.7	2,333,216	7.0
San Diego County	3,022,468	3,289,701	8.8	3,424,184	4.1
California	36,637,290	39,356,104	7.4	40,968,090	4.1

Sources: U.S. Census Bureau 2012,[1] 2023;[2] California Department of Finance 2023[3]

Nevada

In terms of population increases, Nevada represented some of the largest in the analysis areas. Nevada's population grew by 17.9 percent from 2010 through 2022. Clark County's population changed 19.5 percent, which was higher than that of the state overall. Trends are expected to continue with a change of 28.7 percent anticipated in Clark County by 2040 (see **Table TA 17-3**).

Table TA 17-3
Nevada Population 2010–2040

Geographic Area	Population 2010[1]	Population 2022[2]	Percent Change 2010–2022	Estimated Population 2040[3]	Estimated Percent Change 2022–2040
Clark County	1,895,521	2,265,926	19.5	2,916,000	28.7
Nevada	2,633,331	3,104,817	17.9	3,889,575	25.3

Sources: U.S. Census Bureau 2012,[1] 2023;[2] Center for Business and Economic Research 2025; Wright 2025[3]

Utah

Population changes in Utah are moderate compared with other states' analysis area counties. While Kane County had a 9.7 percent increase from 2010 to 2022, the population decreased in Garfield County (1.0 percent) and San Juan County (1.5 percent) over the same time period. Over the next 20 years, the population change is anticipated to accelerate, with a 25.0 percent increase in population predicted for Kane County, 11.4 percent for San Juan County, and 3.4 percent for Garfield County (see **Table TA 17-4**).

For Kane County, the main driver of population growth was net migration to the region of people 65 years and older, with quality-of-life indicators such as outdoor recreation being cited as main factors drawing people to the area (Utah Population Committee 2022).

Table TA 17-4
Utah Population 2010–2040

Geographic Area	Population 2010	Population 2022	Percent Change 2010–2022	Population 2040	Percent Change 2022–2040
Garfield County	5,172	5,121	-1.0	5,294	3.4
Kane County	7,125	7,814	9.7	9,769	25.0
San Juan County	14,746	14,524	-1.5	16,186	11.4
Utah	2,763,885	3,283,809	18.8	4,440,560	35.2

Sources: U.S. Census Bureau 2023; Kem C. Gardner Policy Institute 2023

TA 17.1.2 Industrial and Municipal (Domestic) Water Uses

This section provides a brief overview of municipal water supply, demand, and use trends within the U.S. and the Lower Basin. This section also provides information on the municipalities within

Arizona, California, and Nevada with the potential to be affected by changes in domestic water availability.

Domestic water use includes the use of water for "household, stock, municipal, mining, milling, industrial, and other like purposes," 1922 Colorado River Compact, section II(h). More granularly, this includes indoor and outdoor uses at residences, and uses such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, watering lawns and gardens, and maintaining pools. Domestic water use includes potable and non-potable water provided to households by a public water supplier (domestic deliveries) and self-supplied water use.

Domestic Water Supply, Demand, and Use Trends

Urbanization has increased the percentage of the U.S. population served by municipal water supplies from 70 percent in 1960 to 83 percent in 2021 (Liu et al. 2025). Per capita domestic water use in southwestern states varies regionally: residents in Arizona and Nevada use approximately 126–150 gallons per day, while California residents use 76–100 gallons per day (Chinnasamy et al. 2021; EPA 2025).

Although existing and ongoing municipal water management strategies do not change domestic water entitlement amounts, they illustrate how municipal systems have adapted—and may continue to adapt—to evolving water supply and demand conditions. This context is important for understanding how communities in the region respond to variability in water availability under different future conditions. Municipal water systems in these regions face growing pressures from population growth, climate trends, and uncertainties in future water availability, demand, and technological or policy adoption (Liu et al. 2025). Communities throughout the region have long implemented a range of water management strategies—including conservation programs, demand-side measures, operational changes, and infrastructure investments—to maintain municipal reliability under these evolving conditions.

Structural approaches such as dams, diversions, reservoirs, wastewater treatment facilities, and hydropower systems have historically played a critical role in supporting municipal water supply, while some more recent approaches involve building on existing infrastructure while emphasizing demand-side management through institutional, technological, and behavioral changes (Larson et al. 2016). Strategies can range from implementation of water-use efficiencies, changes to system operations, and demand reduction through water conservation programs. Implementation of water conservation programs has significantly decreased per capita water use (Chinnasamy et al. 2021; DeOreo et al. 2016; Finley and Basu 2020; Price et al. 2014). Water conservation programs in urban areas of the southwestern U.S., including Arizona, California, and New Mexico, have reduced per capita residential water use through targeted demand-side measures (Gleick 2010; Kennedy et al. 2012; Olmstead and Stavins 2009). Programs implementing high-efficiency appliances, leak detection, landscape irrigation restrictions, and tiered pricing reduced per capita demand by roughly 10–15 percent in some cities (Chinnasamy et al. 2021; DeOreo et al. 2016; Finley and Basu 2020; Price et al. 2014).

Across the analysis areas, municipal providers employ a range of adaptation measures to manage supply variability and shortages. In Arizona, measures commonly include demand management and

conservation; increased reliance on groundwater and stored supplies, including recharge and banking, where available; reclaimed water for non-potable demands; and system interconnections or operational changes. In California, measures commonly include conservation; recycled water expansion; stormwater capture and local recharge; groundwater management; interties and transfers, where available; and targeted supply or treatment improvements. In Nevada (Clark County), measures commonly include incentives to reduce outdoor water use, extensive reuse and return-flow management, and storage and exchange arrangements coupled with operational and infrastructure modifications to improve drought resilience. Many measures involve substantial capital costs and multiyear implementation timelines and may be constrained by legal or contractual availability, physical system capacity, water quality and treatment requirements, permitting, energy demands, and environmental considerations, which can limit feasibility or timing for some communities.

The availability of and access to domestic water can influence both population dynamics and land use and development. Population growth can increase the demand for water for domestic, agricultural, and industrial use and increase pressure on existing water sources. Studies have shown that population growth can be a dominant driver of long-term municipal water demand (Liu et al. 2025). Insufficient water supply can constrain population growth and development by limiting an area's capacity to support residents.

Peer-reviewed studies have documented the relationships between population growth, land-use patterns, and domestic water delivery. Urban sprawl, characterized by low-density development and increased impervious surfaces, has been shown to elevate per capita water demand through higher outdoor water use (Heidari et al. 2021). In contrast, high-density development often reduces water use per capita and can lessen the frequency and severity of water shortages. Rapid urbanization and population growth can also increase pressure on existing water infrastructure, creating challenges in maintaining consistent domestic water delivery.

Municipal water demand within the analysis areas is not solely a function of population or economic growth; it can reflect long-term trends in conservation, efficiency, reuse, land-use patterns, the climate, and provider policies. Many municipal providers in the Lower Basin have implemented demand management programs and operational practices that have reduced per capita use over time, such that total municipal demand may remain stable or grow more slowly than the population in some communities. Conversely, the magnitude of realized conservation and the remaining potential for additional cost-effective savings vary by provider due to differences in the existing program maturity, customer mix, climate, built environment, system losses, regulatory constraints, and local supply portfolios.

Municipal planning and development within the Lower Basin counties in the analysis areas rely on assumptions about the reliability, timing, and quality of water supplies used to serve existing and future demands. Within the analysis areas' counties, local governments and water providers typically integrate water supply expectations into general plans, zoning and subdivision decisions, capital improvement programs, and long-range utility master planning. These assumptions inform the sizing and sequencing of major infrastructure (for example, treatment, conveyance, storage, and pressure zones), operational and drought contingency planning, and the ability to maintain service standards under variable hydrologic conditions. Because many providers in these counties manage portfolio

supplies that may include Colorado River–derived deliveries alongside local surface water, groundwater, conservation, reuse, and interconnections, reliability expectations are often expressed not only as an annual volume but also in terms of operational availability during peak demand, drought response triggers, and constraints associated with treatment and regulatory compliance. Accordingly, changes in the reliability of Colorado River supplies can be relevant to municipal planning baselines and the context for evaluating potential effects related to domestic water shortages discussed in **Section TA 17.2.2**.

Water supply has influenced land use and development within the analysis areas. The Arizona Department of Water Resources' (ADWR) Assured and Adequate Water Supply Programs provide a concrete example of how water availability can constrain development. While not directly related to Colorado River water, these programs require developers within active management areas (AMAs) to demonstrate assured or adequate water supplies before recording plats or selling parcels. The Assured Water Supply Program requires that the following seven criteria be met: physical, continuous, and legal availability of water; water quality; financial capability; consistency with AMA management plans, and consistency with AMA management goals. The Adequate Water Supply Program requires demonstration of all criteria, excluding consistency with AMA management plan(s) and goal(s).

The Arizona Department of Real Estate will not issue the public report needed to market lots without such determinations (ADWR 2025). The ADWR's programs illustrate the role of water supply in constraining development, requiring developers to demonstrate reliable water before proceeding (ADWR 2025). This context provides one example of how planning assumptions for water supply relate to residential and commercial development and helps frame how communities might respond to changes in water availability under future conditions.

Domestic water supply reliability also supports baseline employment and community functions across the socioeconomic analysis area. **Section TA 16.1.2** in **TA 16**, Socioeconomics, provides baseline employment by sector for the Arizona, California, Nevada, and Utah counties included in the socioeconomic analysis area for 2010 and 2022 (see **Tables TA 16-1, 16-2, 16-6, 16-7, 16-11**, and **16-14**). These tables provide context for the composition of employment in the analysis areas, including sectors that typically rely on continuous municipal water service to support day-to-day operations and public services. Examples of these sectors include, but are not limited to, information; healthcare and social assistance; retail trade; real estate; arts, entertainment, and recreation; construction; finance and insurance; manufacturing; professional, scientific, and technical services; state and local government; and accommodation and food services. While county-level employment data do not distinguish among the water sources supporting certain sectors and the associated economic activity and public services, the sector employment helps frame domestic water supply, demand, and use trends in the counties included in the socioeconomic analysis area. In models of projected water yield and demand in the western U.S. to 2070, data indicate that demands for municipal water are increasing across the socioeconomic analysis area, while projected water availability is decreasing (see, for example, Warziniack and Brown 2019). While this trend is seen throughout the western U.S., the Colorado River region has the largest percentage increases in projected domestic water use and the greatest percentage decreases in projected water yield from all sources, including Colorado River water (Warziniack and Brown 2019).

TA 17.1.3 Study Area Municipalities

The analysis area is informed by the SAMs and includes the counties represented in the SAMs. Further, the municipalities described below include those represented in the SAMs.

Arizona

Municipalities potentially affected by the alternatives include Arizona municipalities along the Colorado River that have Colorado River water delivery contracts, such as Lake Havasu City, Yuma, and Bullhead City, as well as Phoenix, Tucson, Scottsdale, and other Arizona municipalities and tribal communities within the Central Arizona Project (CAP) service area, which includes more than 80 percent of the state's population (Central Arizona Project 2024). In Arizona, land uses on the Colorado River include the major power facilities of Glen Canyon Dam in Coconino County, Hoover and Davis Dams on the Arizona-Nevada border in Mohave County (and Clark County, Nevada), and Parker Dam in La Paz County (and San Bernardino County, California).

California

Municipalities potentially affected by the alternatives include 7 cities in Imperial County, 88 cities in Los Angeles County, 34 cities in Orange County, 28 cities in Riverside County, 24 cities in San Bernardino County, and 18 cities in San Diego County, as well as many more rural communities around the analysis area that are served by entities that use the Colorado River for water supply (California State Association of Counties 2024). These entities in California that use the Colorado River for water supply include the MWD, Imperial Irrigation District, Desert Water Agency, Coachella Valley Water District, Palo Verde Irrigation District, and tribal reservations (Metropolitan Water District of Southern California 2024).

Nevada

Municipalities potentially affected by the alternatives include Boulder City, Henderson, Las Vegas, Laughlin, and North Las Vegas due to their reliance on Colorado River water supplied by SNWA, which serves more than two million people in Clark County (Southern Nevada Water Authority 2024).

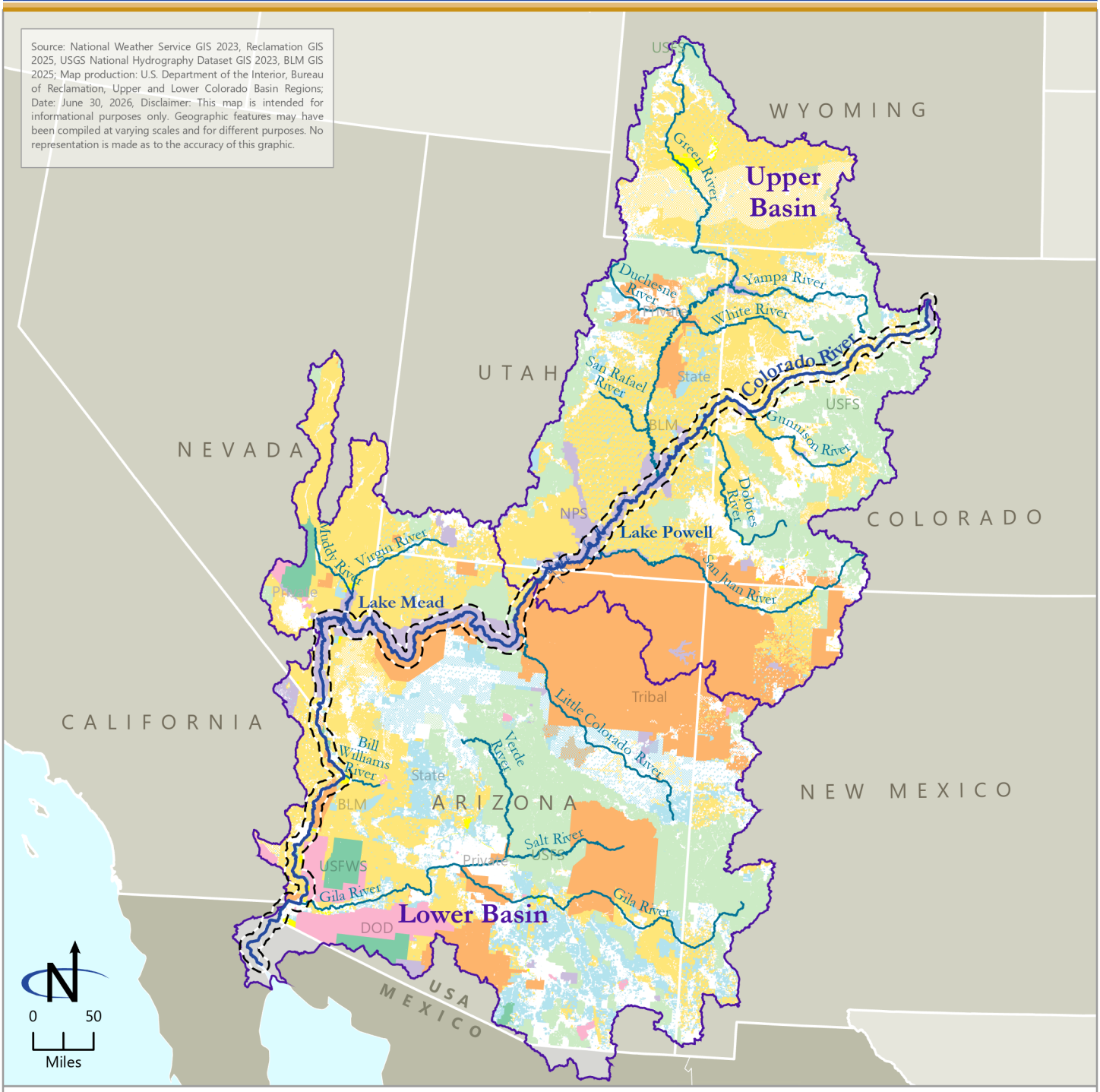
TA 17.1.4 Land Use

Introduction and Scope

This section describes existing land-use conditions along the mainstream Colorado River from Glen Canyon Dam to the U.S.-United Mexican States (Mexico) border. Land use includes recreation, agriculture, tribal land use, conservation and habitat management, residential and urban development, and utility and infrastructure corridors. **Map TA 17-1** shows the landownership.

— BUREAU OF —
RECLAMATION

Map TA 17-1
Land Ownership of the Colorado River Basin



Landownership and Management

Landownership along the Colorado River is highly variable and includes federal (National Park Service [NPS], Bureau of Land Management, U.S. Fish and Wildlife Service, and Reclamation), tribal, state, and private lands. Federal agencies manage much of the land in the upper and middle portions of the river corridor, particularly in areas surrounding Glen Canyon National Recreation Area, Grand Canyon National Park, Lake Mead National Recreation Area, and multiple national wildlife refuges. Tribal lands are prominent in both Arizona and California. State and private lands are more common in the Lower Basin, especially in urban areas like Bullhead City and Yuma, and along agricultural corridors in California and Arizona.

Developed Land Use

Land development has continued across the analysis areas over the past two decades. **Table TA 17-5** to **Table TA 17-8** summarize the number of acres classified as developed in 2001 and 2023 for each county in the analysis area, along with the percentage change during this period. The data are based on U.S. Geological Service (USGS) land cover classifications and provide a snapshot of how developed land has expanded over time. The table shows that most counties experienced growth in developed acreage, though the magnitude of change varies. State- and local-level details are provided in the state sub-sections below. This information establishes a baseline for understanding patterns of land use change within the socioeconomic analysis area and provides context for evaluating potential interactions between land development and Colorado River operations.

Table TA 17-5
Acres of Development from 2001 to 2023 in the Arizona Analysis Area

County in Arizona	Acres Developed[1] in 2001	Acres Developed in 2023	Percent Change
Apache County	45,500	67,400	48
Coconino County	81,000	104,300	29
Gila County	25,100	33,300	33
Maricopa County	544,800	727,400	34
Mohave County	106,100	137,600	30
Navajo County	47,300	65,700	39
Pima County	168,500	227,500	35
Pinal County	129,300	147,800	14
Yuma County	55,100	67,100	22
La Paz County	32,200	35,100	9

Source: USGS 2023

[1] Acreages classified as "developed" include low-, medium-, and high-intensity development or roads. Low-intensity development can include mixed forest, herbaceous, and shrubland cover.

Arizona

Counties in the Arizona analysis area all had an increase in developed land use in the last 20 years. The largest increase was in Apache (48 percent) and Navajo (39 percent) Counties, while Maricopa, Pima, Gila, and Mohave Counties also had 30 percent or more of growth. The smallest increase was in Pinal County (14 percent) and La Paz County (9 percent; **Table TA 17-5**).

California

A few counties in the California analysis area, including Los Angeles, San Diego, and Orange Counties, showed slight declines in developed acreage between 2001 and 2023. These decreases may reflect land reclassification or changes in land-use patterns rather than large-scale removal of development. San Bernardino County had the largest increase in the California analysis area, with 14 percent growth from 2001 to 2023 (see **Table TA 17-6**).

Table TA 17-6
Acres of Development from 2001 to 2023 in the California Analysis Area

County in California	Acres Developed[1] in 2001	Acres Developed in 2023	Percent Change
Imperial County	83,100	86,100	4
Los Angeles County	861,800	833,100	-3
Orange County	305,800	293,400	-4
Riverside County	407,700	425,600	4
San Bernardino County	424,200	483,000	14
San Diego County	479,400	469,600	-2

Source: USGS 2023

[1] Acreages classified as "developed" include low-, medium-, and high-intensity development or roads. Low-intensity development can include mixed forest, herbaceous, and shrubland cover.

Nevada

Compared with other counties in the region, Clark County, Nevada, had robust growth in the past 20 years. At 37 percent, this increase was met or exceeded by only one county in Utah and one in Arizona (see **Table TA 17-7**).

Table TA 17-7
Acres of Development in the Nevada Analysis Area from 2001 to 2023

County in Nevada	Acres Developed[1] in 2001	Acres Developed in 2023	Percent Change
Clark County	214,800	294,000	37

Source: USGS 2023

[1] Acreages classified as "developed" include low-, medium-, and high-intensity development or roads. Low-intensity development can include mixed forest, herbaceous, and shrubland cover.

Utah

Development in some portions of the Utah analysis area, notably Garfield County (37 percent) and Kane County (18 percent), were higher than regional averages from 2001 to 2023. San Juan County, in contrast, saw only a 10 percent increase in developed acres (**Table TA 17-8**).

Table TA 17-8
Acres of Development in the Utah Analysis Area from 2001 to 2023

County in Utah	Acres Developed[1] in 2001	Acres Developed in 2023	Percent Change
Garfield County	28,900	39,700	37
Kane County	17,300	20,400	18
San Juan County	31,000	34,200	10

Source: USGS 2023

[1] Acreages classified as "developed" include low-, medium-, and high-intensity development or roads. Low-intensity development can include mixed forest, herbaceous, and shrubland cover.

TA 17.1.5 Agricultural Land Use

Arizona

In the western U.S., agriculture represents a relatively small share of overall land use, but it requires large amounts of irrigation water. The most water-intensive crops include crops for food, feed, and fiber production. In Arizona, in 2015, irrigated agriculture accounted for about 74 percent of the state's water use; more than 50 percent of this is from surface waters (Dieter et al. 2018). Implementation of certain recent strategies and techniques in the western U.S. has reduced agriculture's share of water consumption. These methods include improvements in irrigation technology, voluntary fallowing programs that compensate farmers who reduce water consumption, and utilization of more effective irrigation strategies, such as changes to irrigation timing and using cover crops to protect the soil (Presson and Eden 2023). However, conservation methods do not reduce the legal water entitlement held by agricultural users.

Pinal, Maricopa, and Pima Counties account for approximately 50 percent of statewide irrigated, harvested cropland (USDA NASS 2024). Colorado River water in these counites is associated primarily with tribal agricultural users receiving CAP water. Agricultural resources in western Arizona are primarily along the Colorado River in Mohave, La Paz, and Yuma Counties and along the Gila River Valley in Yuma County. These western counties account for approximately 32 percent of irrigated agricultural land in Arizona. **Table TA 17-9** provides a summary of county-wide irrigated agricultural lands within the Arizona analysis area.

Production of winter vegetables and leafy greens in the U.S. is seasonally concentrated in the irrigated desert production regions of the Southwest. The U.S. Department of Agriculture's (USDA) Economic Research Service notes that from mid-November through early April, most lettuce sold in the U.S. is sourced from Southern California's Imperial County and the Yuma area of Arizona, and that shipments from Florida help fill in regional market gaps during winter and spring months (Weber 2023).

Table TA 17-9
Irrigated Acres of Harvested Cropland in the Arizona Analysis Area (2022)

Area	Irrigated Harvested Cropland (Acres)	Total Harvested Cropland (Acres)	Percent Irrigated Harvested Cropland to Total Harvested Cropland	Percentage of Statewide Irrigated Harvested Cropland
Maricopa County	202,086	202,092	100	23
Pima County	27,512	27,516	100	3
Pinal County	202,429	202,430	100	23
Total within CAP counties	**432,027**	**432,038**	**100**	**50**
Apache County	5,339	5,369	99	1
Coconino County	511	520	98	0
Gila County	615	618	100	0
La Paz County	80,176	80,176	100	9
Mohave County	(D)	(D)	(D)	(D)
Navajo County	2,876	2,911	99	0
Yuma County	178,842	178,843	100	21
Total Arizona analysis area[1]	**700,386**	**700,475**	**100**	**80**
Total Arizona[1]	**871,746**	**871,863**	**100**	**—**

Source: USDA NASS 2024
(D) = The USDA determined the data are too sensitive to disclose.
— = not applicable
[1] The totals for the Arizona analysis area do not include data for Mohave County because the USDA determined the data were too sensitive to disclose; however, the totals for Arizona include data for Mohave County.

Table TA 17-10 shows changes between 2017 and 2022 in acres of irrigated harvested cropland and in acres of total harvested cropland in each county in the Arizona analysis area. In all counties where data were disclosed, except Maricopa County, there was a decrease in acreage of harvested cropland. In Pima, Pinal, and Gila Counties, this decrease in acreage of harvested cropland corresponded with a similar percent decrease in irrigated harvested cropland. In Navajo and Yuma Counties, the reduction in harvested cropland was largely made up of non-irrigated cropland. In Apache County, the reduction in harvested cropland was fully made up of non-irrigated cropland, and irrigated harvested cropland saw an increase from 2017 to 2022. In Maricopa County, where there was an increase in total harvested cropland, the increase corresponded to an increase in irrigated cropland (USDA NASS 2024).

Table TA 17-10
Irrigation Trend for Harvested Cropland in the Arizona Analysis Area (2017–2022)

Area	Percent Change in Irrigated Harvested Cropland	Percent Change in Total Harvested Cropland
Maricopa County	13.5	7.8
Pima County	-5.6	-5.7
Pinal County	-12.4	-13.9
Total within CAP counties	**-1.4**	**-4.4**
Apache County	23.9	-7.4
Coconino County	(D)	(D)
Gila County	-36.6	-36.5
La Paz County	(D)	(D)
Mohave County	(D)	(D)
Navajo County	-30.2	-50.0
Yuma County	-1.3	-7.7
Total Arizona analysis area[1]	**-1.5**	**-5.8**
Total Arizona[1]	**-0.5**	**-4.8**

Source: USDA NASS 2024
(D) = The USDA determined the data are too sensitive to disclose.
[1] The totals for the Arizona analysis area do not include data for Coconino, Mohave, and La Paz Counties because the USDA determined the data were too sensitive to disclose; however, the totals for Arizona include data for all counties in the state.

Table TA 17-11 shows the proportion of irrigation water that came from all surface water resources in each county in the analysis area in 2015. In Apache County and Maricopa County, where there were increases in irrigated harvested cropland from 2017 to 2022, approximately 94 percent and 21 percent of the irrigated water comes from surface waters, respectively. In Gila County and Navajo County, which had the largest percentage decrease in irrigated harvested cropland from 2017 to 2022, approximately 30 percent and 54 percent of the irrigation water comes from surface waters, respectively (see **Table TA 17-10** and **Table TA 17-11**).

Table TA 17-11
Percentage of Irrigated Water from Surface Water Sources (2015)[1]

Area	Percentage of Irrigated Water Withdrawal for Crops from Surface Waters
Maricopa County	21
Pima County	38
Pinal County	62
Total within CAP counties[2]	**39**
Apache County	94
Coconino County	0
Gila County	30
La Paz County	87
Mohave County	56
Navajo County	54
Yuma County	90
Total within the Arizona analysis area	**61**
Total Arizona	**57**

Source: Dieter et al. 2018
[1] The 2015 USGS water use (for specific purposes, such as irrigation) data by source (surface water or groundwater, etc.) are the most recent available county-level data.
[2] CAP values are the aggregated values of Maricopa, Pima, and Pinal Counties. Surface water sources include all sources; they are not exclusive to the Colorado River.

California

About 96 percent of harvested cropland in the California analysis area is irrigated, which is the same as the percentage of irrigated harvested cropland for California. However, the percentage varies across the counties in the analysis area, ranging from a low of 68 percent in Los Angeles County to a high of 99 percent in San Bernardino County. The proportion of irrigated croplands within the California analysis area represents approximately 11 percent of total irrigated croplands in the state. **Table TA 17-12** shows the acres of irrigated harvested and total harvested cropland within the California analysis area.

Table TA 17-13 shows changes between 2017 and 2022 in acres of irrigated harvested cropland and in acres of total harvested cropland in each county in the analysis area. In Imperial, Los Angeles, and Riverside Counties, there was an increase in the number of acres of harvested cropland and in irrigated harvested cropland. However, in Orange, San Bernardino, and San Diego Counties, there was a decrease in the number of acres of harvested cropland that corresponded to a similar decrease in the number of irrigated harvested cropland acres (USDA NASS 2024).

Table TA 17-12
Irrigated Acres of Harvested Cropland in the California Analysis Area (2022)

Area	Irrigated Harvested Cropland (Acres)	Total Harvested Cropland (Acres)	Percent Irrigated Harvested Cropland to Total Harvested Cropland	Percentage of Statewide Irrigated Harvested Cropland
Imperial County	623,098	634,602	98	8
Los Angeles County	13,876	20,422	68	0
Orange County[1]	3,241	3,299	98	0
Riverside County	166,297	183,926	90	2
San Bernardino County	15,039	15,210	99	0
San Diego County	35,535	37,953	94	0
Total California analysis aarea	**857,086**	**895,412**	**96**	**11**
California	**7,739,236**	**8,081,181**	**96**	**—**

Source: USDA NASS 2024
— = not applicable
[1] The number of irrigated harvested cropland acres was not disclosed for Orange County to avoid publishing confidential information; therefore, the total number of irrigated acres, including harvested cropland, was used as a proxy.

Table TA 17-13
Irrigation Trend for Harvested Cropland in the California Analysis Area (2017–2022)

Area	Percent Change in Irrigated Harvested Cropland	Percent Change in Total Harvested Cropland
Imperial County	36.7	35.8
Los Angeles County	1.7	59.5
Orange County[1]	-23.1	-43.2
Riverside County	32.7	28.1
San Bernardino County	-30.0	-31.3
San Diego County	-14.6	-22.7
Total California analysis area	**29.5**	**27.8**
Total California	**5.3**	**2.8**

Source: USDA NASS 2024
[1] The number of irrigated harvested cropland acres was not disclosed for Orange County to avoid publishing confidential information; therefore, the total number of irrigated acres, including harvested cropland, was used as a proxy.

In California, in 2015, irrigated agriculture accounted for about 74 percent of the state's water use; approximately 27 percent of this was from surface waters (Dieter et al. 2018). **Table TA 17-14** shows the proportion of irrigation water that came from all surface water resources in each analysis area county in 2015. In all counties in the analysis area, approximately 30 percent of the irrigated water comes from surface waters, which is consistent with the state's amount.

Table TA 17-14
Percentage of Irrigated Water from Surface Water Sources (2015 Data)[1]

Area	Percentage of Irrigated Water Withdrawal for Crops from Surface Waters
Imperial County	30
Los Angeles County	30
Orange County	30
Riverside County	30
San Bernardino County	30
San Diego County	30
Total within California analysis area	**30**
Total California	**27**

Source: Dieter et al. 2018
Note: Surface water sources include all sources; they are not exclusive to the Colorado River.
[1] The 2015 USGS water use (for specific purposes, such as irrigation) data by source (surface water or groundwater, etc.) are the most recent available county-level data.

Nevada

Agriculture in the Nevada analysis area—Clark County—is small, with only 2,322 total acres for harvested cropland (USDA NASS 2024). Of the total harvested agricultural lands in Clark County, 100 percent were irrigated cropland, which is similar to the percentage of irrigated cropland in Nevada (99.8 percent; see **Table TA 17-15**). In Nevada, in 2015, irrigated agriculture accounted for about 71 percent of the state's water use; approximately 53 percent of this was from surface waters (Dieter et al. 2018). Approximately 35 percent of the irrigated water in Clark County comes from surface waters (see **Table TA 17-16**).

Table TA 17-15
Irrigated Acres of Harvested Agriculture in the Nevada Analysis Area (2022)

Area	Irrigated Harvested Cropland (Acres)	Total Harvested Cropland (Acres)	Percent Irrigated Harvested Cropland to Total Harvested Cropland
Clark County	2,322	2,322	100.0
Total Nevada	**486,100**	**486,935**	**99.8**

Source: USDA NASS 2024

Table TA 17-16
Percentage of Irrigated Water from Surface Water Sources (2015)[1]

Area	Percentage of Irrigated Water Withdrawal for Crops from Surface Waters
Clark County	35
Total Nevada	**53**

Source: Dieter et al. 2018
Note: Surface water sources include all sources; they are not exclusive to the Colorado River.
[1] The 2015 USGS water use (for specific purposes, such as irrigation) data by source (surface water or groundwater, etc.) are the most recent available county-level data.

TA 17.1.6 Land Use and Management by Reach

Upper Reach (Glen Canyon Dam to Lees Ferry)

This reach is dominated by federal lands managed by the NPS as part of Glen Canyon National Recreation Area. Land use is primarily recreational, with boating, fishing, and sightseeing as the dominant uses. Infrastructure in this reach includes the Glen Canyon Dam and associated access roads. These facilities are sensitive to reservoir elevation changes, and declining water levels may in reduced functionality, relocation needs, or closure.

Grand Canyon Reach (Lees Ferry to Lake Mead)

The NPS manages most land in this reach as part of Grand Canyon National Park. Land use is regulated to preserve natural and cultural resources and to provide for controlled public recreation. Access is limited, and development is minimal. This reach includes tribal lands, which are used for tourism and cultural purposes.

Lower Basin Reach (Hoover Dam to U.S.–Mexico Border)

Land use in this reach is more varied. It includes the following:

- Urban development near Las Vegas, Bullhead City, Lake Havasu City, and Yuma
- Extensive irrigated agriculture in areas such as the Palo Verde and Imperial Valleys
- Recreation and habitat management within national wildlife refuges (Cibola, Havasu, and Imperial)
- Transportation and utility corridors, including transmission lines and canals

Landownership in this reach includes a greater proportion of state and private land, and land use is more intensive compared with upstream reaches. Also, fluctuating water levels can affect the usability of the reach's recreation facilities and require adaptive management, such as ramp extensions, marina relocations, or temporary closures. These infrastructure elements are vital to supporting recreation and tourism in the region and may be affected under the alternatives that result in lower Lake Mead elevations.

Water delivery constraints may influence future land-use decisions in this reach. Some counties could experience changes in agricultural viability and development patterns due to reduced water reliability (see **TA 4**, Water Deliveries).

TA 17.2 Environmental Consequences

TA 17.2.1 Methodology

The analysis of population and land-use impacts evaluates (1) how operational changes and changes to domestic water delivery could affect the overall population and land-use patterns, including developed lands for residential and commercial uses, and (2) how operational changes and changes to irrigation water delivery could affect lands used for irrigated agriculture.

To analyze how operational changes may affect population and land-use patterns (Issue 1), DMDU was applied to the modeled shortage to domestic users provided by the SAMs and Alternative Distribution Models (ADMs). There are three unique SAMs and five Alternative Distribution Models to capture the nuances of the alternatives and sensitivity analyses; these are further explained in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation. **Table C-1** in **Appendix C** provides a crosswalk between the alternatives and SAMs and ADMs. The application of DMDU to analyze domestic water impacts involved multiple steps. First, to capture variation in modeled shortage by priority across the SAMs, the following priority groupings were established: Arizona CAP non-Indian agriculture (NIA)-A and NIA-B (Group 1), Arizona CAP municipal and industrial (M&I) and Priority 4(i) (Group 2), Arizona Priorities 2 and 3 (Group 4), Arizona present perfected right (PPR) (Group 5), California Priority 4 (Group 6), California PPR (Group 7), Nevada Priority 8 (Group 8), Nevada Priorities 1–7 (Group 9). Second, the modeled domestic shortage was analyzed for each of these priority groups, to identify at which shortage level, the average percentage shortage across a given priority group equals approximately 20, 40, 60, 70, 80, or 100 percent of the priority group's total entitlement.

DMDU was then applied to generate **Figure TA 17-1** through **Figure TA 17-8**. These figures are the result of applying SAM-based, volumetric thresholds of the Lower Basin shortage to annual shortage volumes computed from the Colorado River Simulation System. The figures display the percentage of modeled futures in which annual domestic water delivery to a given priority group are always the specified percentage of "normal delivery," across the alternatives. For purpose of this analysis, "normal delivery" is defined as a full Colorado River or CAP entitlement supply. The figures provide a comparison of impacts on domestic water by priority group across the action alternatives. While this appendix focuses on domestic shortage impacts to priority groups, domestic shortage impacts for each entitlement can be found in **Appendix C**. Refer to **Table C-1** and the following tables in **Appendix C** for entitlement-level impacts:

- **Table C-19**, Priority Shortage Allocation Model Domestic Summary
- **Table C-24**, Continuing Current Strategies Shortage Allocation Model Domestic Summary
- **Table C-29**, Lower Basin Priority Shortage Allocation Model Domestic Summary
- **Table C-41**, Pro Rata Alternative Distribution Model Domestic Summary
- **Table C-46**, Lower Basin Pro Rata Alternative Distribution Model Domestic Summary

To analyze how operational changes may affect agricultural land use (Issue 2), the analysis relied on modeled shortages to irrigation users at the state level, produced by the SAMs. For more detailed information on the SAMs and consumptive impacts on irrigation users, see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation**.** For more information on water deliveries and shortage impacts, including those for irrigation, refer to **TA 4**, Water Deliveries.

For analysis of how operational changes may impact socioeconomic conditions related to agriculture, recreation, and nonmarket values and associated county-level socioeconomic data, refer to **TA 16**, Socioeconomics. Because baseline county-level socioeconomic data do not distinguish among water sources supporting economic activity (including non-Colorado River sources or blended supplies), and comparable utility-specific financial and economic modeling inputs are not uniformly available across all municipal providers and service areas in the analysis areas, the analysis in this technical appendix provides a qualitative discussion of municipal impact pathways using the modeled delivery-reliability and shortage outputs from **TA 4**, Water Deliveries. With respect to hydropower and reservoir elevation thresholds, **TA 15**, Dams and Electrical Power Resources, evaluates how the alternatives affect the frequency of operations that would fail to meet customary or desirable firm capacity, energy generation, facility operability, and electricity rate and market value outcomes.

Impact Analysis Areas

The analysis area for the population and land-use section is separated by state and is the same for both population and land-use issues. The impact analysis area is defined by those counties that may be affected by management direction that could result in water shortages to domestic and irrigation users. As described above, both issue statements rely on the SAMs. As a result, the analysis area is informed by the SAMs and includes the counties represented in the SAMs. The Arizona analysis area consists of Apache, Coconino, Gila, La Paz, Maricopa, Mohave, Navajo, Pima, Pinal, and Yuma Counties. These are counties that are directly adjacent to Lake Powell, Lake Mead, or the Colorado River and counties in which shortages would likely occur. The California analysis area consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties. The Nevada analysis area consists of Clark County. The Nevada analysis area was limited to Clark County because Clark County is adjacent to Lake Mead and encompasses SNWA's service area and other individual water providers. Shortages in Nevada would be limited to SNWA's service area.

Assumptions

- Colorado River operations do not directly control population change, but they may indirectly influence migration patterns.
- Local socioeconomic conditions and demographic trends may also be influenced by factors outside river operations, such as housing costs, infrastructure investment, local attitudes toward water conservation, and regional employment patterns.
- In most cases, the contractor, subcontractor, or entitlement holder of an allocation is shown as the entity bearing shortage. In some cases, water allocated to an entitlement holder (for example, a tribal CAP contractor) may lease its allocation to other users (for example, to a non-Indian municipality). The SAMs and ADMs do not attempt to replicate those arrangements, and they only provide approximate estimates at the level of the entitlement

holder, contractor, or subcontractor. The entitlement holder, contractor, or subcontractor to the leasing arrangements would have specific decisions to make during Shortage Conditions to administer those arrangements; Reclamation cannot predict those decisions with sufficient certainty to analyze them in this Final Environmental Impact Statement (EIS).

Impact Indicators

- Shortage to domestic water users
- Acres of developed land within the analysis areas and the potential for changes based on municipal water availability
- Acres of irrigated agricultural land within the analysis areas and the potential for changes based on agricultural water availability

TA 17.2.2 Issue 1: How would operational changes affect population and developed land-use patterns?

This issue examines how different operational strategies may influence population dynamics and developed land-use patterns in communities that rely on Colorado River water for municipal water uses. While Colorado River operations do not directly determine population movement or developed land-use patterns, long-term changes in water availability and recreational access may influence migration patterns and developed land patterns. This issue statement is analyzed by first presenting the DMDU figures and a detailed analysis for domestic water delivery and then by assessing how domestic water delivery changes would impact population and developed land-use patterns.

The analysis for this issue statement evaluates how modeled changes in domestic (municipal) delivery reliability may influence population- and land-use-related outcomes, including constraints on residential and commercial development and potential qualitative effects on existing communities reliant on municipal water supplies. The analysis uses modeled changes in domestic water delivery reliability to understand how communities and land-use-related conditions may be constrained. DMDU results are interpreted as indicators of exposure to domestic shortage and associated impacts; they are not direct forecasts of economic output or sector-specific impacts. Additionally, population is not treated as a direct proxy for consumptive use because conservation, reuse, and local policy can substantially mediate demand. Modeled domestic shortage outcomes are derived from the water deliveries analysis in **TA 4**, Water Deliveries and the shortage allocation frameworks documented in **Appendix C**; because allocations are modeled based on entitlement structures and assumptions, results may not capture all potential place-of-use transfers or future programmatic adjustment that could occur through separate agreements or actions. Quantitative economic impact estimates at the municipality level were not developed across the full analysis area due to inconsistent availability of comparable economic, utility finance, and sector-specific data across all municipal providers; therefore, this appendix describes pathways qualitatively and references related analyses in other sections and appendixes, where applicable.

TA 16, Socioeconomics, provides baseline socioeconomic context for the analysis area, including employment by sector for 2010 and 2022 (**Tables TA 16-1, 16-2, 16-6, 16-7, 16-11**, and **16-14** in **Section TA 16.1.2**). These baseline data describe economic conditions and the composition of

employment in the counties included in the socioeconomic analysis area; however, baseline county-level socioeconomic data do not distinguish among water sources supporting economic activity (including non-Colorado River sources or blended municipal portfolios), and comparable utility-specific financial and economic modeling inputs are not uniformly available across municipal providers and service areas. Accordingly, this appendix does not forecast sector-specific production or employment impacts. Instead, this appendix uses the modeled domestic delivery outcomes and delivery-reliability results reported in **TA 4**, Water Deliveries, together with the modeling frameworks documented in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, discuss qualitative pathways by which reduced municipal delivery reliability may affect community conditions and land-use-related outcomes.

Domestic water delivery impacts are discussed in the context of a DMDU analysis framework. Additional information on the DMDU robustness and vulnerability concepts used to interpret these results is provided in **Appendix E**, DMDU Overview and Approach. Modeling assumptions and shortage allocation frameworks that inform domestic delivery outcomes are documented in **TA 4**, Water Deliveries, and the Final EIS discussion recognizes that adaptation feasibility and constraints vary by location and provider.

In addition to potential constraints on future development, reductions in municipal delivery reliability could affect existing residents and essential services. Severe or abrupt delivery reductions can create operational challenges for conveyance and treatment systems and may affect service reliability depending on local infrastructure and operational constraints. For instance, damage to CAP infrastructure or other diversion facilities can occur under low- or no-flow conditions. In addition, depending on local system configuration and available alternative supplies, severe or abrupt delivery reductions may require additional conservation measures or development of replacement supplies over time. The degree to which these effects would occur, and the time required to adapt, varies by community and is influenced by existing conservation achievements, infrastructure, regulatory requirements, and local hydrologic conditions.

As described in **Section TA 17.1**, water supply reliability is a key input to municipal planning and development. Municipal providers within the analysis area may have structured infrastructure investments, regulatory compliance strategies, and economic development assumptions around continued Colorado River supplies and delivery reliability. Where domestic water shortages reduce available Colorado River deliveries, potential effects may include the need to revise supply planning assumptions; changes in the timing, scale, or sequencing of infrastructure and compliance investments; and constraints or delays affecting planned development or other investments that rely on a defined level of Colorado River domestic water supply. The degree to which these effects may occur would vary by community because municipal supply portfolios, contractual arrangements, demand management capacity, and regulatory contexts differ by provider. Although utility- and project-specific decisions (for example, local growth management actions, capital programming, and rate-setting) would occur outside the scope of this EIS, reduced supplies could increase reliance on alternative sources and require adaptation measures (for example, additional supplies, treatment upgrades, system interconnections, conservation actions, and financing). Such measures can require substantial time and resources to plan, permit, fund, and implement and may not be achievable on the same schedule for all communities.

Similarly, reductions in municipal delivery may result in secondary impacts that may affect the socioeconomic setting and quality of life in affected communities. These impacts may include but are not limited to changes to public and private space landscaping, changes to the quality or availability of recreational opportunities which require water use, impacts to property value, and changes to economic contributions and employment opportunities associated with businesses which rely on domestic water. As noted above, the degree to which these effects would occur varies by community and is influenced by geography (on-river and rural areas), existing conservation achievements, infrastructure, regulatory requirements, adaptation capacity, and local hydrologic conditions.

In evaluating these outcomes, it is important to recognize that the DMDU framework highlights the potential for a wide range of plausible future conditions that cannot be predicted with confidence. Factors such as climate trends, hydrologic change, and evolving population or land-use trends may interact in complex ways that influence domestic water delivery. Therefore, while robustness provides an indicator of how well an alternative performs across many possible futures, decision makers should consider these uncertainties when interpreting results and determining which management approaches are most adaptive and resilient under changing conditions.

Incorporating DMDU principles supports a transparent and adaptive evaluation by considering a range of plausible futures rather than a single forecast. This approach helps decision makers understand the trade-offs, vulnerabilities, and adaptive capacity of each alternative, enhancing the resilience of long-term management strategies.

The alternatives with greater robustness would likely result in fewer potential indirect impacts on population growth and developed land. Greater robustness corresponds to a higher percentage of futures in which domestic water delivery remains consistent with normal conditions and shortages occur less frequently. In contrast, less robust alternatives are more susceptible to reductions in domestic water availability because modeled shortages occur more frequently or the volume of shortage is higher. These shortages could manifest as reduced water deliveries, delivery restrictions, or the need for additional conservation measures, which could in turn limit the capacity to meet domestic water demand. A more robust alternative would therefore help ensure that domestic water supplies remain reliable to support existing populations and accommodate anticipated future growth, thereby minimizing potential secondary impacts on development patterns and land use.

Figure TA 17-1 through **Figure TA 17-8** display potential impacts on domestic water deliveries by presenting the percentage of normal domestic water deliveries that can be achieved across a range of modeled futures. Specifically, each figure shows the percentage of normal domestic water deliveries that can be achieved in 90 percent of years, over a 34-year modeling period, across different percentages of potential futures for each priority group. The metric of 90 percent of years was selected for this analysis, rather than 100 percent of years, because it better displays variation between the alternatives. For each figure, the rows represent different performance thresholds, as percentages of normal domestic water delivery. Higher rows indicate a higher volume of delivery (closer to normal conditions) and are therefore more difficult to achieve across a large percentage of potential futures, while lower rows represent lower levels of delivery that are easier to achieve because they allow for more frequent modeled shortages to domestic water delivery. For this

analysis, greater than 80 percent of normal delivery in 90 percent of years was selected as the minimum level of performance. This row was highlighted because it represents the performance level closest to normal domestic water delivery of the thresholds displayed in the figures, while also representing the earliest point at which differences among alternatives begin to emerge in the DMDU results. In other words, the greater than 80 percent row reflects the least amount of modeled shortage to domestic water users displayed in the figures and is the first row where shortages begin to manifest across alternatives.

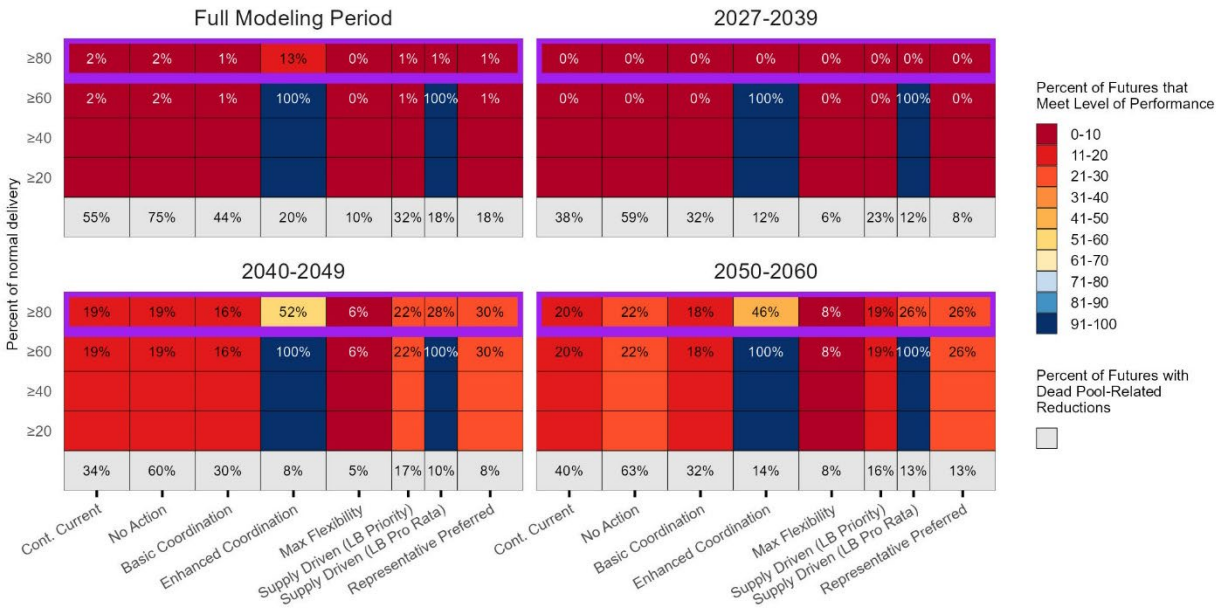
Each figure also displays a row at the bottom for percent futures with dead pool–related reductions. As described in **TA 4**, Water Deliveries, dead pool–related reductions occur when there is not enough water in Lake Mead to fully meet downstream demands and/or when Hoover Dam infrastructure constraints result in releases below the demand volume. In some cases, this occurs because Lake Mead is approaching dead pool (elevation 895 feet) and in some cases it occurs earlier (up to elevation 950 feet). The approach to distributing reductions associated with dead pool is not addressed in this analysis. By providing the information on dead pool–related reductions in the domestic water, the DMDU figures provide additional context on the robustness of the alternatives. **Figure TA 17-1** through **Figure TA 17-8** are described in further detail below.

Figure TA 17-1 through **Figure TA 17-8** display the full modeling period and each of the decadal subperiods within the full modeling period. Across all priority groups, the DMDU modeling results displayed in **Figure TA 17-1** through **Figure TA 17-8** follow a pattern: performance across all alternatives is poorest in the first decade of the modeling period (2027 – 2039). This is because 2027 begins with relatively low reservoir elevations, which results in poorer first decade performance. This is an expected consequence of the initial system state and observed data from the years immediately prior to the modeling rather than a modeling anomaly.

Figure TA 17-1 presents potential shortage impacts on domestic water deliveries to Arizona CAP NIA-A and NIA-B priorities.

Across the first decade of the modeling period (2027–2039), there are no potential futures in which any of the alternatives meet the preferred minimum performance (greater than 80 percent of normal domestic water is delivered in 90 percent of years) for the Arizona CAP NIA-A and NIA-B priorities. Therefore, all alternatives would result in similar impacts on shortage for domestic deliveries to Arizona CAP NIA-A and NIA-B priorities. Under these alternatives, shortages would be high for these users, and domestic deliveries would not be consistent with annual normal delivery.

Figure TA 17-1
Arizona CAP, NIA-A & NIA-B: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



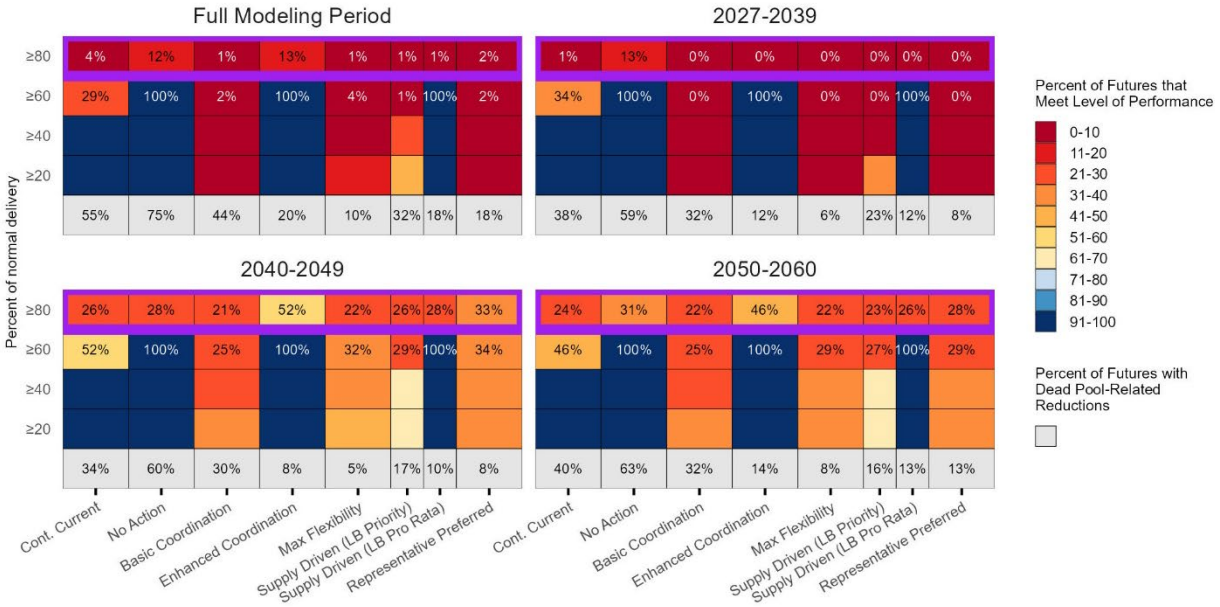
The next level below the preferred minimum performance is greater than 60 percent of normal domestic water delivery to Arizona CAP NIA-A and NIA-B priorities. When considering this next level of performance, the Enhanced Coordination and Supply Driven (Lower Basin Pro Rata [LB Pro Rata] approach) Alternatives are the most robust alternatives for CAP NIA-A and NIA-B priorities compared with all other alternatives, with greater than 60 percent of normal delivery in 90 percent of years occurring in 100 percent of potential futures across the first decade of the modeling period (2027 – 2039). The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives perform well for CAP NIA-A and NIA-B priorities at lower volumes of delivery because they apply pro rata distribution of Lower Basin shortage (shortage is distributed evenly across entitlement holders). Note that with a priority-based distribution, water is distributed to those with more senior water entitlements first, with senior water entitlements facing less shortage. In contrast, with pro rata distribution, shortage is distributed proportionately across all entitlements, regardless of their seniority, with all users bearing some shortage. Therefore, it makes sense that these two alternatives would be the most robust alternative in terms of domestic water delivery to junior priority pools such as the Arizona CAP NIA-A and NIA-B, compared with the other alternatives. If dead pool–related reductions, which may impact these users, are considered, the Enhanced Coordination Alternative remains the most robust alternative compared with the Continued Current Strategies (CCS) Comparative Baseline and the No Action Alternative (as well as all action alternatives).

Under the Representative Preferred Alternative, there are no potential futures in which there is any percentage of normal domestic water delivery to Arizona CAP NIA-A and NIA-B priorities.

However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-1**, above, are not necessarily the anticipated impacts in 2027-2028 under the Preferred Alternative for Arizona CAP NIA-A and NIA-B based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the Lower Basin Priority (LB Priority) approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-2, below, presents potential shortage impacts on domestic water deliveries to Arizona CAP Indian, CAP M&I, and 4(i) priorities.

Figure TA 17-2
Arizona CAP Indian, CAP M&I and 4(i): Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



Across the first decade of the full modeling period (2027–2039), there are no or minimal (less than 0-13 percent) potential futures in which any of the alternatives, meet the selected level of performance (greater than 80 percent of normal domestic water is delivered in 90 percent of years) for the Arizona CAP Indian, CAP M&I, and 4(i) priorities. As displayed in **Figure TA 17-2** above, greater than 80 percent of normal delivery occurs in 13 percent of potential futures under the No Action Alternative and 1 percent of potential futures under the CCS Comparative Baseline. There are no potential futures in which greater than 80 percent of normal delivery to Arizona CAP Indian, CAP M&I and 4(i) priority holders occurs under the Basic Coordination, Maximum Operational Flexibility, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

Under the Enhanced Coordination Alternative, greater than 80 percent of normal delivery occurs in 12 percent and 13 percent of potential futures, respectively. Therefore, when compared with the No Action Alternative, all other alternatives are less robust. While greater than 80 percent of normal delivery occurs in the highest number of potential futures under the No Action Alternative, making it the most robust alternative, it is important to note that this is still a minimal percentage of futures (13 percent). Therefore, there would be potential shortage impacts on domestic water deliveries to Arizona CAP Indian, CAP M&I and 4(i) priority holders across all alternatives.

The next row below the preferred minimum performance is greater than 60 percent of normal domestic water delivery to Arizona CAP Indian, CAP M&I, and 4(i) priorities. When considering this next level of performance, the No Action, Enhanced Coordination, and Supply Driven (LB Pro Rata approach) Alternatives are the most robust for these users compared with the other alternatives, with greater than 60 percent of normal domestic water delivery occurring in 100 percent of futures across the first decade of the modeling period (2027–2039). Under the CCS Comparative Baseline, greater than 60 percent of normal delivery occurs in 34 percent of potential futures. Generally, deeper shortages do not occur for the No Action and Basic Coordination Alternatives and the CCS Comparative Baseline. For the CCS Comparative Baseline and the No Action Alternative, this is because the shortages do not extend far into the apportionments of the Lower Division States. However, it is important to note that for the No Action Alternative and the CCS Comparative Baseline, across the first decade of the modeling period the percentage of futures with dead pool–related reductions are 38 percent and 59 percent, respectively. The No Action, Enhanced Coordination, and Supply Driven (LB Pro Rata approach) Alternatives would result in similar impacts on shortage for Arizona CAP M&I and Priority 4(i). However, if dead pool–related reductions, which may impact these users, are considered, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives are the most robust alternatives for these users compared with the CCS Comparative Baseline and the No Action Alternative (as well as all action alternatives). These two alternatives perform well for domestic entitlement holders at lower volumes of delivery because they use pro rata distributions.

Under the Representative Preferred Alternative, there are no potential futures in which there is any percentage of normal domestic water delivery to Arizona CAP M&I and Priority 4(i) priorities. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-2**, are not necessarily the anticipated impacts in 2027-2028 under the Preferred Alternative for Arizona CAP M&I and Priority 4(i) based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-3, below, presents potential shortage impacts on domestic water deliveries to Arizona Priorities 2 and 3.

Across the first decade of the full modeling period (2027 – 2039), greater than 80 percent of normal domestic water delivery to Arizona Priorities 2 and 3 would occur in 100 percent of potential futures under all the alternatives, excluding the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Pro Rata approach), and Representative Preferred Alternatives. Under the Maximum Operational Flexibility and Representative Preferred Alternatives, on average over the first decade of the modeling period, greater than 80 percent of normal delivery occurs in 26 percent and 54 percent of potential futures, respectively. This is because the Maximum Operational Flexibility and Representative Preferred Alternatives apply priority-based distribution with higher maximum shortage volumes. Under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, greater than 80 percent of normal delivery to Arizona Priorities 2 and 3 occurs in no potential futures. This is because the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives use a pro rata distribution, thus shortage is distributed evenly across entitlement holders regardless of the seniority of water entitlements. Overall, the Supply Driven Alternative (LB Pro Rata approach) is the least robust for these users, followed by the Enhanced Coordination Alternative compared with the other alternatives. Under these alternatives, shortages would be higher, and domestic deliveries would not be consistent with normal annual delivery.

Figure TA 17-3
Arizona Priorities 2 and 3: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



Across the first decade of the modeling period (2027–2039), under the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives and the CCS Comparative Baseline, greater than 80 percent of normal domestic water is delivered to Arizona Priorities 2 and 3 in 100 percent of potential futures. There would be no impacts on domestic shortage for Arizona Priorities 2 and 3, except under the Enhanced Coordination, Maximum Operational Flexibility,

Supply Driven (LB Pro Rata approach), and Representative Preferred Alternatives. Therefore, the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives and the CCS Comparative Baseline would result in similar impacts on shortage for Arizona Priorities 2 and 3. However, if dead pool–related reductions, which may impact these users, are considered, the Supply Driven Alternative (LB Priority approach) is the most robust alternative compared with the CCS Comparative Baseline and No Action Alternative (as well as all action alternatives).

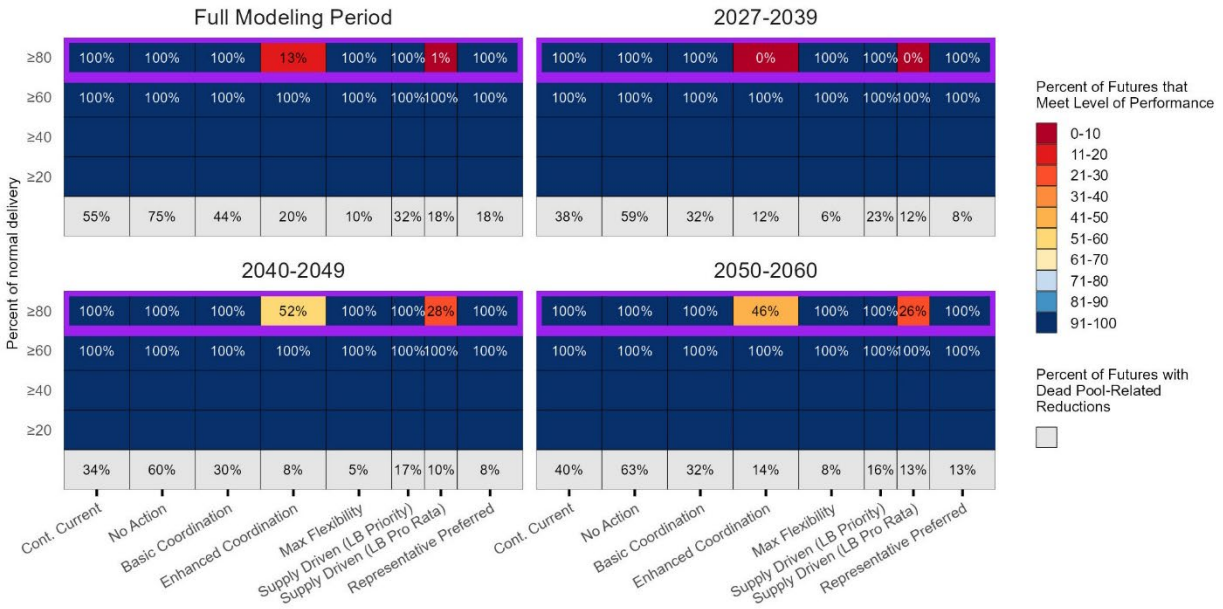
Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to Arizona Priorities 2 and 3 in 54 percent of potential futures under the Representative Preferred Alternative. Greater than 60 percent of normal domestic water is delivered to Arizona Priorities 2 and 3 in 58 percent of potential futures. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-3**, above, are not necessarily the anticipated impacts in 2027-2028 under the Preferred Alternative for Arizona Priorities 2 and 3 based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-4, below, presents potential shortage impacts on domestic water deliveries to Arizona PPR.

Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water delivery to Arizona PPR occurs in 100 percent of potential futures under all alternatives, excluding the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. Under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, greater than 80 percent delivery to Arizona PPR occurs in no potential futures. However, greater than 60 percent of normal delivery occurs in 100 percent of potential futures under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. This is because the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives apply a pro rata distribution, thus shortage is distributed evenly across entitlement holders regardless of the seniority of water entitlements. Under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives (the least robust alternatives for these users), shortages would be higher, and domestic deliveries would not be consistent with annual normal delivery. Under the No Action, Basic Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives and the CCS Comparative Baseline, greater than 80 percent of normal delivery to Arizona PPR occurs in 100 percent of futures. There would be no impacts on shortage for Arizona PPR, except under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. Therefore, the No Action, Basic Coordination, Maximum Operational Flexibility, and Supply Driven (LB Priority approach) Alternatives and the CCS Comparative Baseline would result in similar impacts on shortage for Arizona PPR. However, if dead pool–related reductions, which may impact these users, are considered, the Maximum Operational

Flexibility Alternative is the most robust compared with the CCS Comparative Baseline and the No Action Alternative (as well as all the action alternatives).

Figure TA 17-4
Arizona Present Perfected Rights: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years

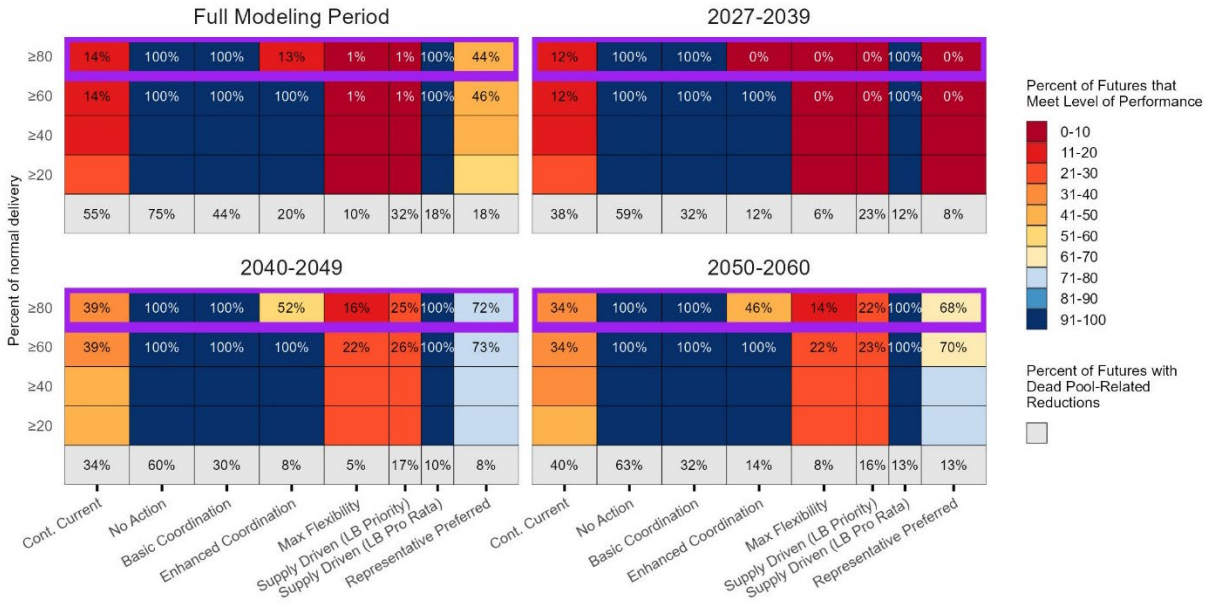


Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to Arizona PPR priority holders in 100 percent of potential futures under the Representative Preferred Alternative. Under this alternative, modeled shortages occur less frequently, and domestic deliveries remain consistent with annual normal delivery for these users.

However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-4**, above, are not necessarily the anticipated impacts in 2027–2028 under the Preferred Alternative for Arizona PPR based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-5, below, presents potential shortage impacts on domestic water deliveries to California Priority 4.

Figure TA 17-5
California Priority 4: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years

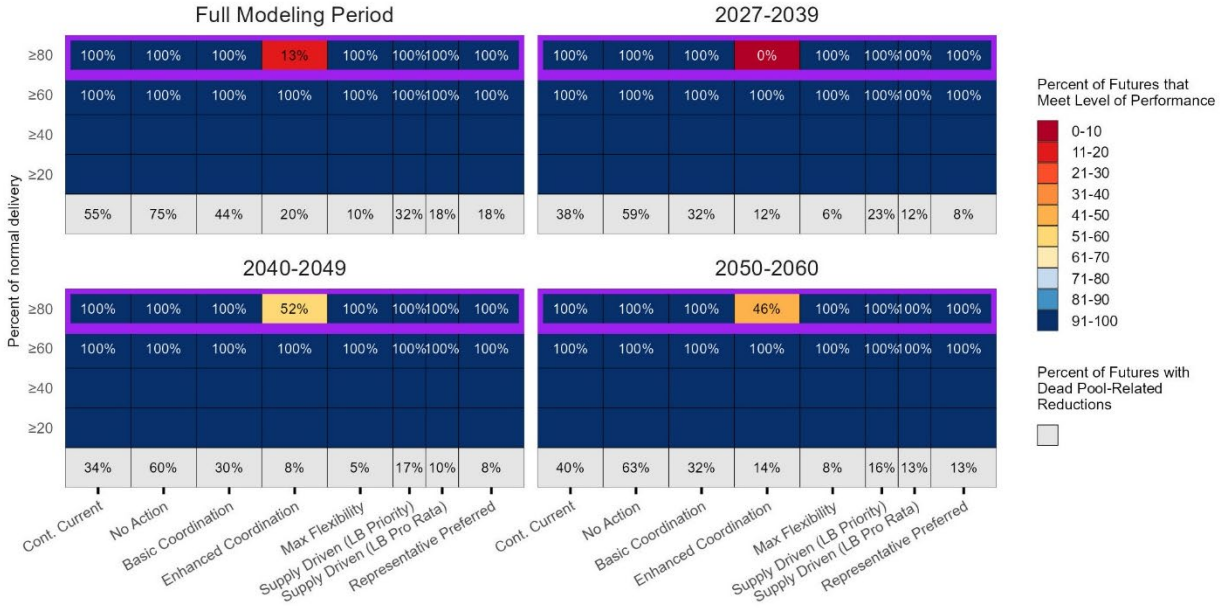


Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to California Priority 4 under the No Action, Basic Coordination, and Supply Driven (LB Pro Rata approach) Alternatives. Under the CCS Comparative Baseline, greater than 80 percent delivery to California Priority 4 occurs in 12 percent of potential futures. Under the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, greater than 80 percent delivery to California Priority 4 occurs in zero percent of potential futures. When compared with the No Action Alternative and the CCS Comparative Baseline, the Supply Driven (LB Pro Rata approach) and Basic Coordination Alternatives are the most robust action alternatives. However, an additional alternative is robust when looking at the next row of normal water delivery: greater than 60 percent of normal delivery. When considering this next level of performance, the No Action, Basic Coordination, Enhanced Coordination, and Supply Driven (LB Pro Rata approach) Alternatives would result in similar impacts on shortage for California Priority 4, with greater than 60 percent of normal domestic water delivery occurring 100 percent of futures across the first decade of the modeling period. However, it is important to note that under the No Action Alternative, there are 59 percent of futures with dead pool–related reductions across the first decade of the modeling period. In contrast, there are 32 percent, 12 percent, and 12 percent of futures with dead pool–related reductions under the Basic Coordination, Enhanced Coordination, and Supply Driven (LB Pro Rata approach) Alternatives across the first decade of the modeling period. When considering dead pool–related reductions, which may impact these users, the Supply Driven Alternative (LB Pro Rata approach) is the most robust, followed by the Basic Coordination Alternative, compared with the CCS Comparative Baseline and the No Action Alternative (as well as all action alternatives).

Across the first decade of the modeling period (2027–2039), there are no potential futures in which there is any percentage of normal domestic water delivery to California Priority 4 under the Representative Preferred Alternative. Under this alternative, modeled shortages occur more frequently, and domestic deliveries would not be consistent with normal annual delivery for these users. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-5,** above are not necessarily the expected impacts in 2027–2028 under the Preferred Alternative for California Priority 4 based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-6, below, presents potential shortage impacts on domestic water deliveries to California PPR.

Figure TA 17-6
California Present Perfected Rights: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to California PPR in 100 percent of potential futures under all alternatives, excluding the Enhanced Coordination Alternative. While there are no potential futures in which greater than 80 percent delivery to California PPR occurs under the Enhanced Coordination Alternative, greater than 60 percent delivery to California PPR occurs in 100 percent

of potential futures under this alternative. Again, this is because the Enhanced Coordination Alternative uses a pro rata distribution, thus shortage is distributed evenly across entitlement holders regardless of the seniority of water entitlements. Because the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives and the CCS Comparative Baseline meet the preferred minimum performance in 100 percent of futures, there is no domestic shortage to California PPR, except under the Enhanced Coordination Alternative. While the all alternatives, excluding the Enhanced Coordination Alternative, would result in similar impacts on shortage, if dead pool–related reductions, which may impact these users, are considered, the Maximum Operational Flexibility Alternative followed by the Representative Preferred Alternative, are the most robust alternatives compared with the CCS Comparative Baseline and the No Action Alternative (as well as all action alternatives).

Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to California PPR priority holders in 100 percent of potential futures under the Representative Preferred Alternative. Under this alternative, modeled shortages occur less frequently, and domestic deliveries remain consistent with annual normal delivery for these users. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-6**, above are not necessarily the expected impacts in 2027–2028 under the Preferred Alternative for California PPR based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

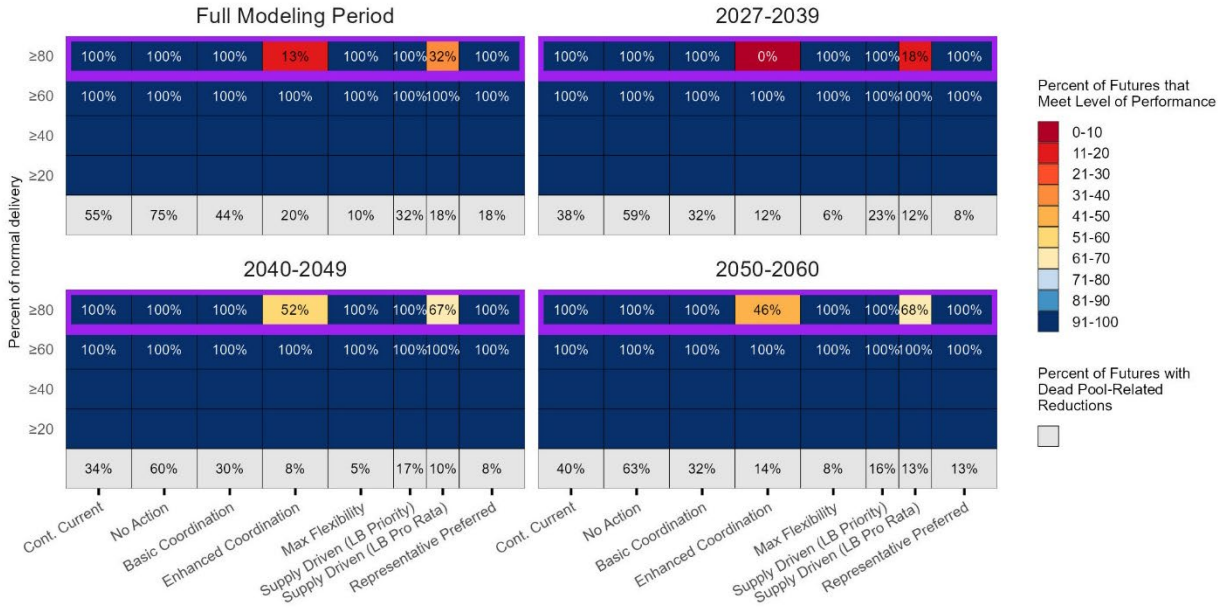
Figure TA 17-7, below, presents potential shortage impacts on domestic water deliveries to Nevada Priorities 1-7.

Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal delivery to Nevada Priorities 1-7 occurs in 100 percent of potential futures under all alternatives, excluding the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. Under the Enhanced Coordination and Supply Driven (LB Priority approach) Alternatives, greater than 80 percent delivery to Nevada Priorities 1-7 occurs in 0percent and 18 percent of potential futures, respectively. This makes sense because the Enhanced Coordination and Supply Driven (LB Priority approach) Alternatives apply a pro rata distribution, where shortage is distributed evenly across all entitlements regardless of the seniority of water entitlements. Under all alternatives, greater than 60 percent of normal delivery occurs in 100 percent of futures.

Across the first decade of the modeling period (2027–2039), greater than 80 percent delivery occurs in 100 percent of potential futures under the CCS Comparative Baseline and the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives. Therefore, there would be no impacts on shortage to Nevada

Priorities 1-7, except under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives. While the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives would result in similar impacts on shortage, if dead pool–related reductions, which may impact these users, are considered, the Maximum Operational Flexibility Alternative followed by the Representative Preferred Alternative, are the most robust alternatives compared with the CCS Comparative Baseline and the No Action Alternative (as well as all action alternatives).

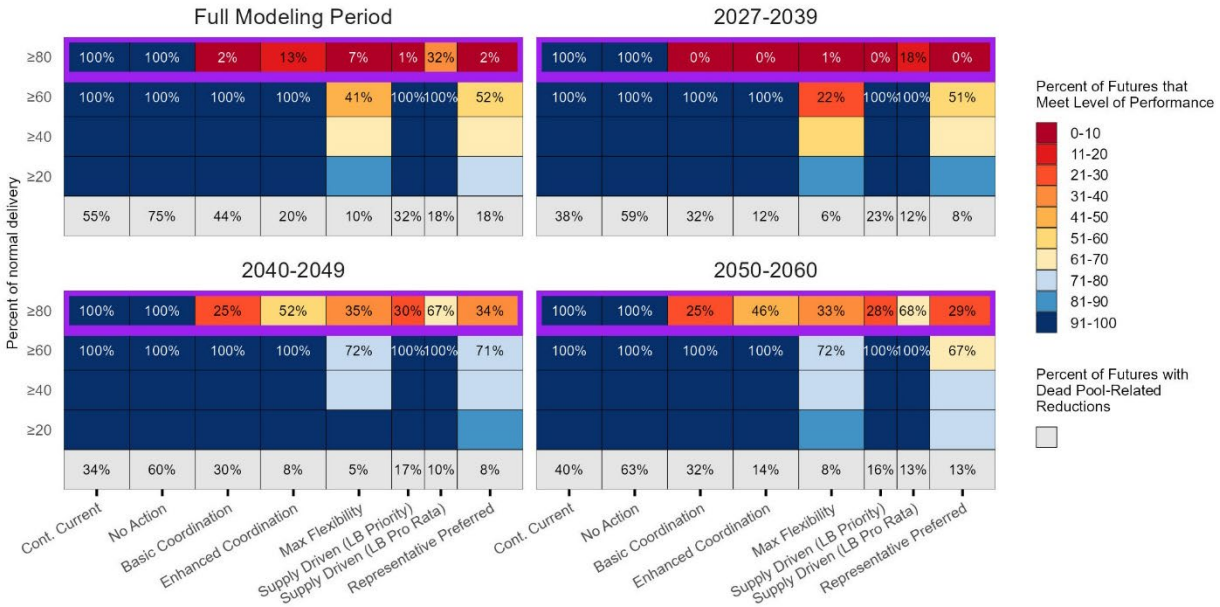
Figure TA 17-7
Nevada Priorities 1-7: Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



Across the first decade of the modeling period (2027–2039), greater than 80 percent of normal domestic water is delivered to Nevada Priorities 1-7 in 100 percent of potential futures under the Representative Preferred Alternative. Under this alternative, modeled shortages occur less frequently, and domestic deliveries remain consistent with annual normal delivery for these users. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-7**, above are not necessarily the expected impacts in 2027–2028 under the Preferred Alternative for Nevada Priorities 1-7 based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

Figure TA 17-8, below, presents potential shortage impacts on domestic water deliveries to Nevada Priority 8.

Figure TA 17-8
Nevada Priority 8 (Including Balance and Surplus): Robustness
Percentage of futures in which annual delivery is the percentage of normal domestic delivery specified in each row in at least 90 percent of years



Across the first decade of the modeling period (2027–2039), greater than 80 percent delivery to Nevada Priority 8 (including Balance and Surplus) occurs in 100 percent of futures under the CCS Comparative Baseline and the No Action Alternative. For all other alternatives, the percentage of potential futures in which greater than 80 percent of normal delivery occurs varies. Under both the Basic Coordination, Enhanced Coordination, Supply Driven (LB Priority approach), and Representative Preferred Alternatives greater than 80 percent of normal delivery occurs in no potential futures. Under the Maximum Operational Flexibility and Supply Driven (LB Pro Rata approach) Alternatives, greater than 80 percent delivery to Nevada Priority 8 occurs in 1 percent and 18 percent of potential futures, respectively. Generally, deeper shortages do not occur for the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives. For the CCS Comparative Baseline and the No Action Alternative, this is because the shortages do not extend far into Nevada's apportionment. However, it is important to note that for the CCS Comparative Baseline and the No Action Alternative, the percentage of futures with dead pool–related reductions are 38 percent and 59 percent, respectively, across the first decade of the modeling period.

The next level below the preferred minimum performance is greater than 60 percent of normal domestic water delivery to Nevada Priority 8. Across the first decade of the modeling period, greater than 60 percent of normal delivery occurs in 100 percent of futures for all alternatives except the Maximum Operational Flexibility and Representative Preferred Alternatives. The Maximum Operational Flexibility Alternative, followed by the Representative Preferred Alternative, are the

least robust compared with the other alternatives, because Maximum Operational Flexibility and Representative Preferred Alternatives apply a priority-based distribution with higher maximum shortage volumes. When considering this next level (greater than 60 percent delivery), and considering dead pool–related reductions, the Basic Coordination, Enhanced Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are the most robust compared with the other alternatives, with greater than 60 percent of normal domestic water delivery occurring in 100 percent of futures across the first decade of the modeling period. Additionally, when considering dead pool–related reductions, which may impact these users, dead pool–related reductions would be lowest under the Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. Overall, the Enhanced Coordination, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would result in similar impacts on shortage. However, when considering dead pool–related reductions, which may impact these users, the Supply Driven Alternative (LB Pro Rata approach) and the Enhanced Coordination Alternative would be the most robust compared with the CCS Comparative Baseline and the No Action Alternative (as well as all action alternatives). Under these alternatives, modeled shortages occur less frequently, and domestic deliveries remain consistent with normal annual delivery for these users.

Across the first decade of the modeling period (2027–2039), there are no potential futures in which greater than 80 percent of normal domestic water is delivered to Nevada Priority 8 under the Representative Preferred Alternative. Greater than 60 percent of normal domestic water is delivered to Nevada Priority 8 in 51 percent of potential futures. Under this alternative, modeled shortages occur more frequently, and domestic deliveries would not be consistent with normal annual delivery for these users. However, the modeling results in 2027-2039 for the Representative Preferred Alternative displayed in **Figure TA 17-8**, above are not necessarily the expected impacts in 2027–2028 under the Preferred Alternative for California Priority 4 based on the May 1 proposal by Lower Division States, which represents the best available information at the time of publication. This proposal would distribute shortage according to the LB Priority approach. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results are heavily influenced by shortages in 2029-2039, which are distributed according to the Priority distribution. See **Chapter 2** and **Appendix C**, **Table C-1** for additional information. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage).

TA 17.2.3 DMDU Analysis Summary

The DMDU analysis allows for comparison of the alternatives in terms of potential shortage impacts on domestic entitlements. When comparing the domestic water impacts, it is important to note that a more robust alternative results in a higher percentage of potential futures where domestic water delivery remains consistent with normal conditions and shortages occur less frequently. Conversely, a less robust alternative yields fewer futures with normal domestic water delivery and a higher frequency of shortages.

The SAMs used to inform the DMDU analysis do not incorporate water management measures such as conservation programs or demand-reduction strategies. These measures do not change entitlement amounts or shortages; however, as described in the affected environment section,

conservation programs and other management strategies can influence domestic water demand and help mitigate the operational pressures associated with shortage, uncertain supply, and population growth. Therefore, while the model results presented here do not capture these measures, the potential impacts of shortages on domestic water supply for the Lower Basin would also depend in part on existing and future conservation and management actions implemented by states, local water providers, and individual users. Potential impacts would also depend on other external factors such as environmental and economic conditions.

Communities and municipal providers may respond to shortages through a range of adaptation measures, which could include increased conservation and demand management, use of existing storage or water banking arrangements where available, investments in infrastructure (for example, treatment upgrades, reuse, interconnections), operational changes, or pursuit of alternative supplies and agreements. The feasibility, timing, and effectiveness of these measures would vary by location and provider, and may be constrained by physical and geographic availability of replacement water, jurisdictional and legal limitations (including state-law and contractual considerations), the time required for planning, permitting, financing, and construction, and constraints related to existing infrastructure configurations and prior investments. Adaptation measures may also involve direct and indirect economic costs to providers and ratepayers and may require trade-offs among objectives under different future conditions. Consistent with the DMDU framework, these uncertainties and constraints should be considered when interpreting robustness results and evaluating the extent to which an alternative can reduce both direct delivery impacts and potential secondary effects on development patterns and land use. **Table TA 17-17**, Summary of Potential Effects on Domestic Water by Alternative, below, provides an overview of impacts on domestic water by alternative based on the DMDU figures discussed in detail above. The table demonstrates how the different alternatives perform in terms of percentage of normal delivery in potential futures. **Table TA 17-17** includes two performance indicators: greater than 80 percent of normal delivery and greater than 60 percent of normal delivery in 90 percent of potential futures, across the first decade of the modeling period. The table displays how each alternative performs for these two performance indicators, by priority group. The performance indicators illustrate how each alternative performs in maintaining domestic water deliveries under a wide range of uncertain future conditions. The alternatives that would achieve greater than 80 percent of normal delivery in 90 percent of years demonstrate strong robustness, indicating that domestic deliveries would remain near normal levels across most modeled futures. These alternatives would result in fewer and less severe shortages, which would provide greater reliability for domestic water users. This performance indicator is difficult to achieve under many alternatives. To show further variation across the alternatives, **Table TA 17-17** includes greater than 60 percent of normal delivery in 90 percent of years. The alternatives that only meet the greater than 60 percent of normal delivery in 90 percent of years threshold demonstrate lower robustness. Under these conditions, more frequent domestic delivery reductions or shortages could occur in modeled futures, particularly for junior priority groups. Such outcomes could increase the likelihood of secondary socioeconomic impacts, including constraints on growth or secondary changes in land development patterns.

As shown in **Table TA 17-17**, for the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, which apply a priority-based distribution of shortage, under most modeled futures, water users with senior

entitlements would likely continue to experience relatively consistent domestic water deliveries, as these entitlements are contractually prioritized during periods of reduced supply. However, junior entitlements could face greater reductions in water deliveries during Shortage Conditions. Consequently, while senior entitlement holders may maintain service levels closer to normal, junior entitlement holders could experience more frequent or severe delivery constraints.

As shown in **Table TA 17-17**, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which apply pro rata distribution of shortage, under most modeled futures, would generally allow a larger number of priority groups to receive domestic water deliveries closer to normal conditions. While a pro rata approach would change the distribution of water across all users during shortages, this section solely focuses on the distribution of water to domestic users. This approach would deviate from the priority-based distribution, resulting in some modeled reductions to domestic deliveries for some senior entitlement holders who would otherwise maintain normal domestic delivery under the existing priority system. In contrast, more domestic junior priority water entitlement holders continue to receive some level of water supply under this approach. In general, the pro rata method would result in more existing users receiving moderate water deliveries during shortages through a redistribution of water from senior entitlements.

As described in **Section TA 17.1**, Affected Environment, peer-reviewed studies document that domestic water availability significantly influences population dynamics and land use. To provide a high-level overview of potential impacts on domestic water and the associated impacts on population and land-use patterns, key summaries are also provided below for Arizona, California, and Nevada.

Table TA 17-17
Summary of Potential Effects on Domestic Water by Alternative

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
Priority Group: Arizona CAP NIA-A and NIA-B	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.[1]	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.
Priority Group: Arizona CAP Indian, M&I, and 4(i)	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period.. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**13 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.

[1] Normal delivery refers to a full supply of Colorado River water throughout this table.

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.
Priority Group: Arizona Priorities 2 and 3	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**26 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**54 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**35 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**58 percent** of modeled futures meet the performance definition.

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
Priority Group: Arizona PPR	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.
Priority Group: California Priority 4	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
Priority Group: California PPR	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.
Priority Group: Nevada Priorities 1-7	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**18 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
Priority Group: Nevada Priority 8	Percentage of potential futures in which greater than 80 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the more robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**1 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.	**18 percent** of modeled futures meet the performance definition.	**0 percent** of modeled futures meet the performance definition.
	Percentage of potential futures in which greater than 60 percent of normal domestic delivery occurs 90 percent of the time, across the first decade of the modeling period. The higher the percentage, the robust an alternative is with respect to achieving normal domestic deliveries.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**22 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**100 percent** of modeled futures meet the performance definition.	**54 percent** of modeled futures meet the performance definition.
What are the trade-offs between alternatives?	Shortage to domestic water users across the first decade of the modeling period (2027–2039).	N/A	>80 percent of normal domestic water delivery to some senior entitlements (AZ P2 & P3; AZ PPR; CA PPR; and NV P1-7 priority groups) and some junior entitlements (CA P4 priority group) occur in all potential futures. In contrast, for junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); and NV P8 priority groups) there are no potential futures in which >80 percent normal domestic water delivery occurs. NV P8 receives >60 percent of normal domestic water delivery in all potential futures.	>60 percent of normal domestic water delivery to all Arizona, California, and Nevada priority groups occurs in all potential futures. While this alternative results in more priority groups receiving domestic water delivery closer to normal conditions, it results in domestic shortage impacts on Arizona, California, and Nevada senior entitlements that would otherwise receive domestic water deliveries consistent with normal conditions.	>80 percent of normal domestic water delivery to some senior priority groups (AZ PPR; CA PPR; and NV P1-7 priority groups) occurs in all potential futures. In contrast, for all Arizona, California, and Nevada junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); CA P4; and NV P8 priority groups) there are no potential futures, in which >80 percent of normal domestic water delivery occurs. AZ P2 & P3 receives >60 percent and >80 percent of normal delivery in 26 percent and 35 percent	>80 percent of normal domestic delivery to some senior entitlements (AZ P2 & P3; AZ PPR; CA PPR; and NV P1-7 priority groups) occur in all potential futures. In contrast, for junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); CA P4; and NV P8 priority groups), there are no potential futures, in which >80 percent of normal domestic water delivery occurs. NV P8 receives >60 percent of normal domestic water delivery in all potential futures.	>80 percent normal domestic water delivery occurs in all potential futures for all California priority groups. >60 percent of normal domestic delivery to all Arizona and Nevada priority groups occurs in all potential futures. While this alternative results in more Arizona junior priority groups receiving domestic delivery closer to normal conditions, it results in domestic shortage impacts on Arizona and Nevada senior entitlements that would otherwise receive	>80 percent of normal domestic water delivery to some senior priority groups (AZ PPR; CA PPR; and NV P1-7 priority groups) occurs in all potential futures. In contrast, for all Arizona, California, and Nevada junior entitlements (AZ CAP NIA-A and NIA-B; AZ CAP Indian, M&I, and 4(i); CA P4; and NV P8 priority groups) there are no potential futures, in which >80 percent of normal domestic water delivery occurs. AZ P2 & P3 receives >60 percent and >80 percent of normal delivery in 54 percent and 58 percent

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	Basic Coordination Alternative	Enhanced Coordination Alternative	Maximum Operational Flexibility Alternative	Supply Driven Alternative (LB Priority approach)	Supply Driven Alternative (LB Pro Rata approach)	Representative Preferred Alternative
What are the trade-offs between alternatives? *(continued)*	*(see above)*	*(see above)*	There are no potential futures in which Arizona junior priority receive any percentage of normal domestic water delivery. While this alternative results in all senior priority groups and some California junior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to Arizona junior priority groups.	*(see above)*	of potential futures, respectively. NV P8 receives >60 percent and >80 percent of normal domestic water delivery in 1 percent and 22 percent of potential futures, respectively. There are no potential futures in which Arizona and California junior entitlements receive any percentage of normal domestic water delivery. While this alternative results in Arizona and California PPR and Nevada senior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to all Arizona and California junior priority groups.	AZ CAP Indian, M&I, and 4(i) receives >20 percent of normal domestic water delivery in 31-40 percent of potential futures. There are no potential futures in which Arizona CAP NIA-A and NIA-B and CA P4 priority groups receive any percentage of normal domestic water delivery. While this alternative results in all senior priority groups receiving domestic water delivery closest to normal conditions, it results in severe domestic shortage impacts to some Arizona and California junior priority groups.	deliveries consistent with normal conditions.	of potential futures, respectively. NV P8 receives >60 percent and >80 percent of normal domestic water delivery in 0 percent and 51 percent of potential futures, respectively. There are no potential futures in which Arizona and California junior entitlements receive any percentage of normal domestic water delivery. While this alternative results in Arizona and California PPR and Nevada senior priority groups receiving domestic water delivery closest to normal conditions, it results in domestic shortage impacts to all Arizona and California junior priority groups.

Impact Category	Performance Indicator	Impacts Summary						
		No Action Alternative	**Basic Coordination Alternative**	**Enhanced Coordination Alternative**	**Maximum Operational Flexibility Alternative**	**Supply Driven Alternative (LB Priority approach)**	**Supply Driven Alternative (LB Pro Rata approach)**	**Representative Preferred Alternative**
How would operational changes affect irrigated agricultural land-use patterns?	Acres of irrigated agricultural land within the corridor and potential for changes based on agricultural water availability.	Frequent and severe shortages for junior priority irrigation users likely lead to fallowing, crop switching, and long-term land retirement in Arizona CAP counties; Imperial Valley remains protected.	Capped shortages reduce extreme outcomes but concentrated impacts in Arizona still drive significant agricultural land-use changes; California remains insulated.	Pro rata distribution mitigates concentrated impacts but introduces broader reductions, increasing risk of widespread crop switching and fallowing in both Arizona and California.	Large shortage volumes and reliance on conservation participation create high uncertainty; potential for extensive land retirement if participation is low.	Concentrates impacts on junior users, preserving senior districts but accelerating land-use change in Arizona CAP counties.	Distributes shortages broadly, increasing exposure for California and potentially leading to widespread fallowing and crop switching across the Basin.	The representative preferred alternative for 2027-2028 would result in shortages, with impacts concentrated on junior users. In the longer term (2029-2060) modeled outcomes indicate potential for additional fallowing land and crop switching, with impacts concentrated on junior users. However, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative, as a result, the potential for fallowing, crop switching, and other associated long term land - use patterns in any given area may vary and impacts may be mitigated in part by specific operational guidelines.

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Arizona: Figure TA 17-1 through **Figure TA 17-4** display potential impacts on domestic water deliveries for Arizona priority groups**.** Across the first decade of the modeling period, the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives would result in similar impacts on water supply for more senior entitlements (Arizona Priorities 2 and 3 and Arizona PPR), with greater than 80 percent of normal delivery occurring in 100 percent of potential futures. In other words, there would be no domestic shortage impacts for Arizona PPR and Priorities 2 and 3 under these alternatives. However, potential impacts do vary under the other action alternative for these two priority groups. Under all alternatives, excluding the Enhanced Coordination Alternative, 100 percent of normal delivery to Arizona PPR occurs in 100 percent of potential futures. Under the Maximum Operational Flexibility and Representative Preferred Alternatives, greater than 80 percent of normal delivery to Arizona Priorities 2 and 3 occurs in 26 percent and 54 percent of potential futures, respectively. Compared with the No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives, the Maximum Operational Flexibility and Representative Preferred Alternatives are more robust with respect to achieving normal domestic deliveries to Arizona PPR and less robust with respect to achieving normal domestic deliveries to Arizona Priorities 2 and 3. When considering dead pool–related reductions, which may impact these users, the Supply Driven Alternative (LB Priority approach) is the most robust of the alternatives, followed by the Basic Coordination Alternative, with respect to achieving normal domestic deliveries to more senior entitlements (Arizona Priorities 2 and 3 and PPR). Under these alternatives, there is a higher percentage of potential futures where domestic water delivery to Arizona PPR, Priority 2, and Priority 3 remains consistent with normal conditions. A higher percentage of potential futures with greater than 80 percent of normal delivery could support existing communities, future population growth, water demand, and development in areas serviced by these priority groups. Because the Basic Coordination and Supply Driven (LB Priority approach) Alternatives have greater robustness for Arizona PPR, Priority 2, and Priority 3, there could be fewer potential indirect impacts on population and land-use-related outcomes for existing communities and on future population growth and land development.

In contrast, the CCS Comparative Baseline, and the Basic Coordination, Maximum Operational Flexibility Supply Driven (LB Priority approach), and Representative Preferred Alternatives would result in similar impacts on shortage for more junior entitlements (Arizona CAP NIA-A, CAP NIA-B, CAP Indian, M&I, and 4(i)), with greater than 80 percent delivery occurring between 0 and 1 percent of potential futures. Further, under the Basic Coordination, Enhanced Coordination, and Representative Preferred Alternatives, there are no potential futures in which Arizona CAP NIA-A, CAP NIA-B, CAP Indian, M&I, and 4(i)) priority groups receive any percentage of normal domestic water delivery. Under these alternatives, there is a higher frequency of shortage and no potential futures in which normal domestic delivery to these priorities occurs. Shortages could manifest as reduced water allocations, delivery restrictions, or the need for additional conservation measures, limiting the capacity to meet domestic water demand. A higher frequency of shortages and fewer potential futures with normal domestic delivery to these junior priorities could result in potential impacts on municipalities and communities that rely on domestic water delivery under these entitlements. Under the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, Arizona CAP NIA-A, CAP NIA-B, CAP Indian, M&I, and 4(i)) could experience less reliable water delivery for existing populations and future population growth, secondary impacts on land use and development

patterns, and decreased capacity to respond to water demands. As described in **TA 4**, Water Deliveries, maximum shortage to junior entitlements is highest under the Maximum Operational Flexibility Alternative. Should shortages result in a reduction or elimination of legal access to municipal water, widespread impacts on social and economic conditions may also be possible. Further, the shortage distributions applied under these alternatives could result in the complete loss of domestic water for these users. Some third-party studies evaluate potential socioeconomic impacts under specific scenarios and assumptions. For example, a 2026 report describes categories of potential economic impacts that could occur under reduced CAP deliveries (WestWater 2026)[2]. While the WestWater 2026 report is scenario-specific, it is cited here to provide examples of the nature and types of potential impacts and pathways that may occur under reduced CAP deliveries (that is, direct, indirect, and induced economic impacts affecting employment, population, and housing). In some scenarios, municipalities may find the need to pursue adaptation measures including alternative water sources, or hauled water if available, as an alternative to support continued services. However, adaptation measures (for example, new supplies, infrastructure, treatment, interconnections, and related financing) can require substantial time and resources and may not be available on the same schedule for all communities. While these specific local project decisions would occur outside the scope of this Final EIS, it is important to note the potential for impacts. In addition, indirect social costs may occur as a result of a reduction in ecosystem services, or benefits to people provided by the environment. For example, trees in urban areas have been shown to provide high levels of benefits to people in the form of shade, which mitigates impacts of urban heat (that is, heat-related illness),[3] local air quality improvements, and enhancement of the visual setting. Should a reduction in domestic water supply result in die-offs of urban and suburban area trees, this could represent a loss of value that would take decades to recapture, due to the growth time required for trees (see, for example, Bloome et al. 2016).

The DMDU figures do not capture individual years within the modeling period, however, they are modeled. The modeling assumptions for the Representative Preferred Alternative in the first two years (2027–2028) are described in **Chapter 2** and the shortages up to 1.5 maf are distributed via LB Priority. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage). **TA 4**, Water Deliveries, shows analysis of the Representative Preferred Alternative for 2027 and 2028 at the state distribution level. The potential 2027 and 2028 operating guidelines modeling is compared to the Representative Preferred Alternative in **Appendix T,** Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028. The results for the Representative Preferred Alternative in 2029–2036, in which the Priority distribution is applied, would result in more shortage impacts on Arizona junior entitlements. Impacts beyond 2028 under the Preferred Alternative may be different from what is shown in the DMDU figures for the Representative Preferred Alternative, as this

[2] Because this study is scenario-specific and not directly comparable to the Draft EIS modeling framework, the Final EIS does not adopt quantified estimates from this study.

[3] Sudeep Sinha et al., Variation in Estimates of Heat-Related Mortality Reduction Due to Tree Cover in U.S. Cities, 301 J. Envtl. Mgmt. 113751 (2022); Darin J. Jenerette et al., Micro-Scale Urban Surface Temperatures Are Related to Land-Cover Features and Residential Heat-Related Health Impacts in Phoenix, AZ (USA), 31 Landscape Ecology 745-60 (2016); Peder Ibsen et al., Urban Tree Cover Provides Consistent Mitigation of Extreme Heat in Arid but Not Humid Cities, 113 Sustainable Cities & Soc'y 105677 (2024).

alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**.

When considering all Arizona priority groups, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives generally demonstrate the most robust performance for domestic water entitlements, based on maintaining greater than 60 percent of normal delivery in at least 90 percent of years across the first decade of the modeling period, for the greatest number of users. Compared with the CCS Comparative Baseline and the No Action Alternative, under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, 60 percent or more of normal domestic water delivery occurs across the largest percentage of potential futures and for the greatest number of priority groups. While this approach maximizes delivery reliability for more users overall, it involves a trade-off: senior entitlements would experience delivery reductions that would not occur under a priority distribution, whereas more junior entitlements may continue to receive near-normal deliveries, across the modeled futures. This allocation reflects a balance between broad delivery coverage and the reallocation of shortage risk across the priority groups.

California: Figure TA 17-5 through **Figure TA 17-6** display potential impacts on domestic water deliveries for California priority groups**.** Under the No Action, Basic Coordination, and Supply Driven (LB Pro Rata approach) Alternatives, greater than 80 percent of normal delivery occurs in 100 percent of potential futures for California PPR and Priority 4. In other words, there would be no impacts on domestic shortage for California PPR and Priority 4, under these alternatives. However, potential impacts do vary under the other action alternative for these two priority groups. Under all alternatives, excluding the Enhanced Coordination Alternative, 100 percent of normal delivery to California PPR occurs in 100 percent of potential futures. Under all alternatives, excluding the Enhanced Coordination Alternative, there would be no shortage to California PPR across modeled futures. When considering dead pool–related reductions, which may impact California PPR, the Maximum Operational Flexibility and the Representative Preferred Alternatives are the most robust compared with other alternatives, with the lowest percent of potential futures with dead pool–related reductions (6 percent and 8 percent across the first decade of the modeling period, respectively). Therefore, with the greatest frequency of normal domestic water delivery, these alternatives would result in the least potential impacts on domestic water for California PPR. However, for California Priority 4, deliveries greater than 80 percent of normal delivery occurs in no potential futures under the Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives. Therefore, under these alternatives modeled delivery reductions could result in impacts to existing residents, economic sectors, and essential services reliant on domestic deliveries. Communities could experience increased constraints on existing and new residential and commercial development, need for additional adaptation measures, and greater pressure to accelerate development of replacement supplies. When evaluating both California priority groups together, the Supply Driven Alternative (LB Pro Rata approach) is the most robust compared with the No Action Alternative and all other action alternatives. It provides 100 percent of normal delivery to California PPR and California Priority 4 in 90 percent of years across 100 percent of potential futures. Additionally, considering the dead pool–related reductions, which could affect these users, the Supply Driven Alternative (LB Pro Rata approach) has the third lowest percentage of futures with constrained releases (12 percent) across the first decade of the modeling period, compared with all other alternatives. Reliable domestic water deliveries under the Supply

Driven Alternative (LB Pro Rata approach) would support existing communities, continued population growth, and land development in areas served by California PPR and Priority 4. Maintaining near-normal deliveries across modeled futures supports the capacity for planned and new development, housing availability, and municipal services that rely on water supply. In contrast, the alternatives with lower reliability or greater exposure to dead pool–related reductions could limit opportunities for residential and commercial growth, particularly areas experiencing high population growth, intensive development, or elevated municipal water demand, and could influence land-use patterns or delay new construction. Ensuring robust water delivery across multiple futures is therefore an important factor supporting existing communities, sustainable population growth, and land-use planning in California.

The DMDU figures do not capture individual years within the modeling period, however, they are modeled. The modeling assumptions for the Representative Preferred Alternative in the first two years (2027–2028) are described in **Chapter 2** and the shortages up to 1.5 maf are distributed via LB priority. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage). **TA 4**, Water Deliveries, shows analysis of the Representative Preferred Alternative for 2027 and 2028 at the state distribution level. The potential 2027 and 2028 operating guidelines modeling is compared to the Representative Preferred Alternative in **Appendix T,** Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028. The results for the Representative Preferred Alternative in 2029–2036, in which Priority distribution is applied, would result in more shortage impacts on Arizona junior entitlements. Impacts beyond 2028 under the Preferred Alternative may be different from what is shown in the DMDU figures for the Representative Preferred Alternative, as this alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**. Nevada: Figure TA 17-7 and **Figure TA 17-8,** display potential impacts on domestic water deliveries for Nevada priority groups**.** Under all alternatives, except the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, 100 percent of normal delivery to Nevada Priorities 1–7 occurs in 90 percent of years across 100 percent of potential futures. Under the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, deliveries greater than 80 percent of normal to both priority groups occurs in only 13 percent and 32 percent of potential futures, respectively.

The CCS Comparative Baseline and No Action Alternative result in similar outcomes for both Nevada priority groups—Priorities 1–7 and Priority 8—with 100 percent of normal delivery to each group occurring in 90 percent of years across 100 percent of potential futures. However, it is important to note that for the No Action Alternative and the CCS Comparative Baseline, across the first decade of the modeling period the percentage of futures with dead pool–related reductions are 38 percent and 59 percent, respectively.

For Nevada Priorities 1–7 specifically, the Maximum Operational Flexibility Alternative is the most robust, followed by the Representative Preferred Alternative, compared with the No Action Alternative and the other action alternatives. In contrast, for Nevada Priority 8, these same alternatives are some of the least robust, with deliveries greater than 80 percent of normal occurring in only 1 percent of potential futures (Maximum Operational Flexibility Alternative) and no potential futures (Representative Preferred Alternative).

When considering both Nevada priority groups together, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives provides the most robust performance. These alternatives deliver greater than 60 percent of normal domestic water across the largest percentage of potential futures and for the greatest number of priority groups. Robust domestic water deliveries are critical to supporting existing communities and population growth and land development in Nevada. The alternatives that maintain more reliable deliveries across modeled futures for both priority groups support the capacity for existing and new housing, commercial development, and essential municipal services that depend on water supply. Conversely, alternatives with lower reliability, particularly for Nevada Priority 8, could result in impacts to the capacity to support existing residents, economic sectors, and essential services reliant on domestic deliveries. Communities could experience increased constraints on existing and new residential and commercial development, impacts on the capacity of communities to expand, and effects on land-use patterns or delays to new construction projects. Modeled delivery reductions could result in the need for additional adaptation measures, and greater pressure to accelerate development of replacement supplies. By sustaining domestic water availability across a broad range of potential futures, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives may help support existing residents, economies, and essential services; stable population growth; and more predictable land-use planning across the state, where modeled deliveries remain reliable.

The DMDU figures do not capture individual years within the modeling period, however, they are modeled. The modeling assumptions for the Representative Preferred Alternative in the first two years (2027–2028) are described in **Chapter 2** and the shortages up to 1.5 maf are distributed via LB Priority. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage). **TA 4**, Water Deliveries, shows analysis of the Representative Preferred Alternative for 2027 and 2028 at the state distribution level. The potential 2027 and 2028 operating guidelines modeling is compared to the Representative Preferred Alternative in **Appendix T**, Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028. The results for the Representative Preferred Alternative in 2029–2036, in which Priority distribution is applied, would result in more shortage impacts on Arizona junior entitlements. Impacts beyond 2028 under the Preferred Alternative may be different from what is shown in the DMDU figures for the Representative Preferred Alternative, as this alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**.

TA 17.2.4 Issue 2: How would operational changes affect irrigated agricultural land-use patterns?

This issue examines how different operational strategies may influence land-use patterns associated with irrigated agriculture, and the potential for long-term changes to these land uses based on Colorado River water availability for this use. While agricultural producers may pursue adaptive responses such as crop switching in response to reduced water availability, the feasibility of these responses may be constrained by local conditions and may involve additional costs or risks. Additional discussion of the economic implications of agricultural responses, including fallowing, is provided in the **TA 16,** Socioeconomics.

Estimated water shortages for Lower Basin agricultural users are shown in **Table TA 17-18**, by modeling approach and alternative. Additional details related to the shortage allocation model estimates are included in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation. An overview of state levels shortages for all uses is included in **TA 4**, Water Deliveries. Potential broader market responses (for example, production shifts to other regions, imports, and price effects) are uncertain and were not explicitly modeled in this analysis, which focuses on irrigation water availability and potential land-use response in the analysis area.

The analysis of impacts to irrigation water deliveries relies on data outputs from the SAM. Irrigation shortage and subsequent impacts to users is directly correlated to reservoir releases: please see **TA 3** Hydrologic Resources, **Section 3.2.3.**, for a detailed analysis of reservoir releases.

The CCS Comparative Baseline reflects Colorado River operations from recent years, incorporating the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead, the 2019 Drought Contingency Plan, Minute 323 of the 1944 United States-Mexico Water Treaty on Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, and related agreements. These strategies have supported a mix of voluntary conservation, Intentionally Created Surplus (ICS) banking, and coordinated shortage responses that have helped buffer impacts on land use, particularly in urban and agricultural areas. While shortages still occur under the CCS Comparative Baseline, the framework provides more predictability and flexibility than the No Action Alternative, which reverts to pre-2007 operations. As a result, land-use patterns, including irrigated agriculture and urban development, are more likely to remain stable under the CCS Comparative Baseline, especially in areas with access to ICS or conservation programs. However, long-term viability of water-dependent land uses may still be challenged by declining reservoir elevations and increasing demand pressures.

While the CCS Comparative Baseline framework offers structure and predictability, modeled results illustrate how these outcomes vary between states and across different shortage levels, reflecting the continued vulnerability of certain user groups. Irrigation users in Arizona experience greater reductions under alternatives with pro rata distribution approaches at lower to mid-level system shortage volumes because currently most irrigators hold higher priority entitlements, and allocating reductions proportionally results in larger volumetric impacts than the priority-based framework. Although existing conservation and management measures help moderate impacts, irrigation reductions are still expected and may influence land use decisions such as fallowing or crop switching. Existing literature supports these findings, showing that sustained irrigation reductions in Arizona, particularly among junior priority users, have already led to reduced farm income and localized economic contraction (Arizona Extension 2024). In contrast, California's agricultural users experience relatively greater shortages only under higher system shortage volumes, consistent with the state's senior water rights structure that provides protection under moderate conditions but may require larger contributions during more severe shortages. Studies in California similarly indicate that even modest reductions in irrigation can result in shifts toward drought tolerant crops and eventual land retirement in more vulnerable areas (Prakash 2023). Overall, while the CCS Comparative Baseline provides greater predictability than the No Action Alternative, the long-term viability of irrigated agriculture in Arizona and California may still be challenged by persistent shortages and declining reservoir conditions.

Table TA 17-18
Agricultural Water Shortage by State by Alternative

	Irrigation Shortage Impacts		Total Shortage Volume (acre-feet)									
	Modeling Approach	**EIS Alternative**	**600,000**	**1,000,000**	**1,500,000**	**1,800,000**	**2,000,000**	**2,100,000**	**2,300,000**	**3,000,000**	**3,600,000**	**4,000,000**
Arizona	CCS	CCS Comparative Baseline[1]	7,975	13,145								
	Priority	No Action Alternative	6,053									
	Priority	Basic Coordination Alternative[2]	6,053	18,557	34,188							
	ProRata	Enhanced Coordination Alternative	54,569	90,948	136,421	163,706	181,895	190,990	209,179	272,843		
	LB Priority	Maximum Operational Flexibility Alternative	2,240	9,240	17,991	27,231	33,391	36,471	42,631	161,121	311,267	411,364
	LB Priority	Supply Driven (LB Priority Approach) Alternative	2,240	9,240	17,991	27,231	33,391	36,471				
	LB ProRata	Supply Driven (LB Pro Rata Approach) Alternative	107,558	157,945	220,930	244,651	260,465	268,371				
	LB Priority	Representative Preferred (2027-2028) Alternative[3]	2,240	9,240	17,991	27,231	33,391	36,471	42,631	161,121	311,267	
	Priority	Representative Preferred (2029-2060) Alternative[4]	6,053	18,557	34,188	43,566	44,007	56,296	97,889	243,044	367,463	
California	CCS	CCS Comparative Baseline[1]	0	14,000								
	Priority	No Action Alternative	0									
	Priority	Basic Coordination Alternative[2]	0	0	0							
	ProRata	Enhanced Coordination Alternative	261,020	435,034	652,551	783,061	870,068	913,571	1,000,578	1,305,102		
	LB Priority	Maximum Operational Flexibility Alternative	0	0	51,998	51,998	51,998	51,998	51,998	347,920	618,857	799,481
	LB Priority	Supply Driven (LB Priority Approach) Alternative	0	0	51,998	51,998	51,998	51,998				
	LB ProRata	Supply Driven (LB Pro Rata Approach) Alternative	98,132	228,974	392,527	533,837	628,044	675,147				
	LB Priority	Representative Preferred (2027-2028) Alternative[3]	0	0	51,998	51,998	51,998	51,998	51,998	347,920	618,857	
	Priority	Representative Preferred (2029-2060) Alternative[4]	0	0	0	0	0	0	0	224,262	534,032	

Note: The highlighting shows the values from the smallest (in white or no highlighting) to the largest (in yellow highlighting). The cells with hash-marks represent the values above shortages; these values are outside of the scope of this analysis. See the Shortage Allocation and Alternative Distribution Models (**Appendix C**) for more information on the shortage values for each entitlement holder type above shortages.

[1] Due to its fixed shortage volumes for the CCS Comparative Baseline, shortages for 600,000 acre-feet and 1 million acre-feet (maf) are actually associated with 613,000 acre-feet and 1.013 maf in the CCS Comparative Baseline. Greater shortages are based on an extension of priority beyond the levels of shortage provided by the pertinent documents.

[2] The maximum shortage for the Basic Coordination Alternative is 1.48 maf, however, the table above shows the maximum shortage as 1.5 maf for ease of comparison across the alternatives.

[3] The distribution of shortages up to 1.5 maf in 2027-2028 in the Representative Preferred Alternative reflects the May 1 proposal by the Lower Division States. Although not specified in their proposal, the Representative Preferred assumes shortages and their distribution above 1.5 maf in 2028 as necessary to avoid critically low elevations in Lake Mead. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative and their representation in the Representative Preferred Alternative).

[4] Expected impacts from 2029–2060 under the Preferred Alternative may be different from what is shown for the Representative Preferred (2029–2060) Alternative, as this alternative provides a framework that allows for shortage distributions to be negotiated in different ways, consistent with sideboards described in **Chapter 2**.

Without conservation mechanisms or coordinated flexibility, agricultural users face more severe impacts. Conservation mechanisms can support water deliveries by increasing usable system supply and providing operational buffers, without altering the delivery priority hierarchy unless an alternative explicitly modifies it. Water banking and groundwater savings facilities allow participating entities to reduce immediate diversion, store conserved water in reservoir accounts, and recover water later when needed, helping to maintain deliveries during shortage periods. Under the No Action Alternative, no new conservation mechanisms are introduced, and shortages are distributed by priority. Agricultural users with junior entitlements (i.e. Priority 4(i) users in La Paz, Mohave, and Yuma Counites in Arizona, see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model, for additional details) would likely experience frequent and severe reductions in water deliveries because they rely heavily or entirely on surface water, may also face increased fallowing. The lack of flexibility in water management due to the absence of operational or conservation mechanisms could exacerbate long-term declines in irrigated acreage, especially in counties already showing downward trends in harvested cropland (USDA 2025). Analysis of water productivity across the Colorado River Basin (Basin) shows that Lower Basin counties, particularly in Arizona and California, generate higher crop revenue per acre-foot of water applied than Upper Colorado River Basin regions. This suggests that reductions in agricultural water deliveries in these areas could have disproportionately high economic impacts, reinforcing the need for more adaptive water management strategies (Bickel et al. 2024). Under the No Action Alternative, Lake Mead is projected to fall below dead pool in 75 percent of modeled futures, which could constrain releases to downstream users. These constraints may result in reduced water availability for urban and agricultural land uses, potentially leading to fallowing, development delays, or infrastructure abandonment in affected counties (see **TA 4**, Water Deliveries). The No Action Alternative offers slight improvement in predictability due to capped shortages, but not necessarily meaningful change in agricultural water reliability or land-use outcomes.

These modeled outcomes are further supported by additional analyses that examine how physical and policy-based delivery constraints under deteriorating hydrologic conditions would exacerbate agricultural vulnerabilities. Under the No Action Alternative, modeled capacity constraints occur frequently enough that irrigation users in Arizona and California would face reductions that exceed existing policy-level shortage mechanisms. Without continuation of current shortage-sharing and conservation mechanisms, this alternative exposes Arizona and California to heightened risks of physical delivery constraints as reservoir elevations decline. Literature from USGS, 2019 and Prakash, 2023 indicates that when water availability is constrained by infrastructure or operational limits, agricultural users often experience abrupt and severe reductions in supply, leading to land retirement, fallowing, and associated economic disruption. In Arizona, such outcomes could accelerate land-use changes in Yuma, Mohave, and La Paz counties, while in California, even senior priority districts may be affected if physical shortages become the limiting factor in water supply. These findings highlight the increased vulnerability of irrigated agriculture under conditions of limited operational flexibility and deteriorating hydrologic reliability.

The Basic Coordination Alternative introduces a capped shortage mechanism, offering modest improvements in predictability but few new tools for agricultural resilience. This alternative retains the priority-based shortage distribution of the No Action Alternative but introduces a capped shortage volume of 1.48 maf. While this cap is intended to ensure that an assumed minimum flow is

available for infrastructure protection and delivery for municipal use by CAP users and other Fourth Priority mainstem entitlement holders in Arizona when mainstream shortage is distributed by priority, it does not establish new agricultural conservation mechanisms to offset reductions through stored or deferred diversions. As a result, agricultural users in Arizona and California, especially those with junior entitlements, continue to face significant reductions in water deliveries.

The increase in capped volume may reduce the frequency of extreme shortages compared with the No Action Alternative, but the absence of conservation pools means agricultural land use remains highly vulnerable. In Arizona, La Paz, Mohave, and Yuma Counties may see increased fallowing and economic stress in farming communities. California's Imperial Valley would not experience shortages, but other regions could experience similar pressures. The capped shortage volume provides marginal improvement in predictability, but agricultural water reliability and land-use outcomes remain largely unchanged from the No Action Alternative.

Detailed modeling results reinforce this outcome, showing that although the capped shortage slightly moderates total reductions, its benefits remain distributed by priority across states and users. The Basic Coordination Alternative irrigation shortages follow a pattern similar to the No Action Alternative but are capped at a system-wide reduction up to the policy-level cap of 1.48 maf. Within this range, Arizona bears all modeled irrigation shortages, while California experiences none, consistent with the continuation of existing priority structures. Because this alternative maintains the current priority framework and does not change delivery priorities, shortages follow existing priority rules. As a result, junior priority users, including both irrigation and domestic users within Arizona Priority 4, continue to bear the largest reductions. The resulting reductions increase the likelihood of fallowing, crop switching, and economic stress in affected agricultural communities, potentially leading to long-term land-use changes such as farmland retirement (Presson and Eden 2023).

By comparison, the Enhanced Coordination Alternative incorporates conservation pools and reductions that distribute shortages across more users and increase operational flexibility. This alternative introduces coordinated reservoir operations and conservation pools in Lake Powell (2 maf) and Lake Mead (5 maf), with shortages distributed pro rata across Lower Basin water users. This represents a departure from the No Action Alternative's priority-based approach.

Agricultural users in Arizona benefit from a broader distribution of shortages, reducing the likelihood of concentrated fallowing impacts among junior users. Arizona counties (Yuma, Mohave, and La Paz) and California's Imperial Valley see enhanced stability relative to the No Action Alternative due to conservation pool access. The pro rata distribution method ensures that agricultural users across states share reductions more evenly, mitigating the concentrated impacts seen under the No Action Alternative for juniors.

This alternative supports the continuation of some irrigated agriculture across the Basin, with the potential to sustain a measure of productivity across all priorities. Compared with the No Action Alternative, it provides a more resilient framework for some level of irrigated agriculture under a range of hydrologic conditions. Studies suggest that pro rata reductions tend to spread fallowing and crop switching more broadly, whereas priority-based approaches protect senior-rights districts but concentrate impacts on lower-priority users (Lee et al. 2020; Prakash 2023; USDA ERS 2021).

The quantitative results under the Enhanced Coordination Alternative mirror these operational changes, demonstrating how pro rata allocation redistributes impacts across states. Irrigation shortages in Arizona are generally larger than those under the No Action and Basic Coordination Alternatives when total shortage volumes are low. However, when total shortage volumes are above 3.5 maf, irrigation shortages are smaller than under those alternatives because of the coordinated, pro rata shortage allocation across Lower Basin water users. This approach reduces the concentration of impacts on Arizona's junior priority irrigation users but results in a broader distribution of shortages across states, meaning California's agricultural users, typically protected under priority-based operations, would experience increased reductions. Literature suggests that such shared reductions may lessen localized land-use impacts but increase regional exposure. Prakash (2023) found that more equitable shortage sharing often encourages widespread adoption of efficient irrigation practices and crop switching, particularly in regions such as the Imperial Valley and Yuma County. While these adjustments may enhance long-term resilience, the higher overall shortage volumes modeled under this alternative could still contribute to land retirement and economic stress in water-dependent regions (USGS 2019; Arizona Extension 2024).

While the Enhanced Coordination Alternative emphasizes shared reductions, the Maximum Operational Flexibility Alternative expands management tools even further, allowing for the largest potential shortages (up to 4 maf) and includes a Conservation Reserve (up to 8 maf) shared across basins. While this introduces flexibility not included in the No Action Alternative, it also increases exposure to extreme shortage scenarios. Agricultural users in Yuma, La Paz and Mohave Counites may face high risk of fallowing unless conservation participation is robust. The Conservation Reserve allows users to store water in either Lake Powell or Lake Mead and convert it to system water when needed, offering a buffer against extreme shortages. California's agricultural regions benefit from similar flexibility, though effectiveness depends on participation and reservoir conditions. Compared with the No Action Alternative, this alternative introduces tools for adaptation and resilience, but agricultural outcomes depend heavily on conservation engagement and interbasin cooperation.

Modeling results under this framework underscore the same theme: flexibility can help smooth impacts under moderate conditions but cannot fully offset risks to agricultural viability under prolonged shortages. The Maximum Operational Flexibility Alternative modeled irrigation shortages in Arizona are similar to those under the Supply Driven Alternative (LB Priority approach). This alternative incorporates operational flexibility based on hydrologic conditions and system storage, which helps moderate shortages during less severe periods. California experiences smaller but more consistent irrigation reductions through the middle range of system shortages, though less than under the alternatives using pro rata distribution. Overall, this approach maintains a priority-based structure while introducing adaptive mechanisms that influence the timing and distribution of irrigation impacts across the Colorado River Basin. Literature indicates that the flexibility introduced under this alternative may help buffer irrigation impacts during less severe hydrologic periods, though its effectiveness depends on conservation participation. Conservation programs have helped stabilize water availability, but long-term reductions still pose risks. USDA ERS (2021) notes that irrigated agriculture increasingly relies on adaptive strategies such as deficit irrigation and crop switching to maintain productivity. In both Arizona and California, these adjustments may lead to

shifts in land use toward fallowing or land retirement and may reduce the economic viability of certain crops.

The Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) decouples Lake Powell and Lake Mead operations and analyzes both priority-based and pro rata shortage distribution schemes. This dual-path approach allows for more nuanced control than the No Action Alternative, which relies solely on priority-based allocation.

Under priority-based allocation, agricultural users with junior entitlements, particularly in Arizona, would face impacts similar to those under the No Action Alternative. However, under pro rata distribution, impacts are more evenly spread, reducing impacts on Arizona counties and increasing impacts on senior priorities, primarily in California. The conservation pools in Lake Powell (3 maf) and Lake Mead (8 maf) offer conservation mechanisms, and the phased conversion of existing ICS may add further flexibility.

Compared with the No Action Alternative, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) has the potential to improve agricultural outcomes, particularly under the Supply Driven Alternative (LB Pro Rata approach). However, its effectiveness depends on implementation details, stakeholder agreements, and conservation participation. It offers a more tailored approach that distributes shortages across a broader set of users, changing how agricultural water deliveries are managed compared with the other alternatives.

Further detail from the two modeled approaches of the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) clarifies how different allocation schemes affect the scale and distribution of irrigation shortages, revealing important trade-offs between distribution of reductions, magnitude of reductions, and overall agricultural outcomes. Under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), modeled irrigation shortages reach the policy-level cap at 2.1 maf. Under the Supply Driven Alternative (LB Priority approach), Arizona and California are modeled as splitting the irrigation reductions unevenly. In contrast, under the Supply Driven Alternative (LB Pro Rata approach), the reductions would be distributed more evenly and more heavily on California as the modeled shortage increases. While this approach reduces concentrated impacts in Arizona, it introduces greater irrigation reductions for California's agricultural users than under the other alternatives. Overall, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) reflects a trade-off between distribution and magnitude of impact, with broader distribution of shortages but higher total volumes of shortage to irrigators. Literature indicates that pro rata reductions are more likely to result in widespread fallowing and crop switching, while priority-based approaches preserve senior-rights districts but concentrate impacts (Lee et al. 2020; Prakash 2023; USDA ERS 2021). In both cases, sustained irrigation reductions are expected to influence land-use decisions and economic outcomes across the Basin. (Prakash 2023; USDA ERS 2021).

The Preferred Alternative provides additional flexibility to develop operational guidelines based on conditions. Up to 1.5 maf, the Representative Preferred (2027-2028) Alternative would result in shortages similar to those under the Maximum Flexibility and the Supply Driven (LB Priority approach) Alternatives, with impacts concentrated on junior users.

In the longer term (2029-2060) modeled outcomes for the Representative Preferred Alternative follow the priority approach for distribution, indicate potential for fallowing of land as noted under the Basic Coordination Alternative, with impacts concentrated on junior users. Unlike the Basic Coordination Alternative, the Representative Preferred (2029-2060) Alternative policy-level shortage caps are not applied until 3.6 maf, therefore there is the potential for higher levels of shortage with increased potential for fallowing and land use changes. However, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative, as a result, the potential for fallowing, crop switching, and other associated long term land -use patterns in any given area may vary and impacts may be mitigated in part by specific operational guidelines.

TA 17.2.5 Summary Comparison of Alternatives

Population and Developed Land Use – The alternatives vary in how they distribute domestic shortages and, in their potential, to impact domestic water deliveries and, in turn, indirectly impact population dynamics and land use within the analysis area.

As shown in **Table TA 17-17**, for the No Action, Basic Coordination, Maximum Operational Flexibility, and Supply Driven (LB Priority approach), and Representative Preferred Alternatives, which apply a priority-based distribution of shortage, under most modeled futures, water users with senior entitlements would likely continue to experience relatively consistent domestic water deliveries. This is because these entitlements are contractually prioritized during periods of reduced supply. However, junior entitlements could face greater reductions in water deliveries during Shortage Conditions. Consequently, while senior entitlement holders may maintain service levels closer to normal, junior entitlement holders could experience more frequent or severe delivery constraints.

Under the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, greater than 80 percent of normal domestic delivery to most senior entitlements occurs in all potential futures. The specific Arizona, California, and Nevada senior entitlements vary by alternative (see **Table TA 17-17**). Because these alternatives have greater robustness for senior priority groups there could be fewer potential indirect impacts on existing communities as well as population growth and land development. A higher percentage of potential futures with greater than 80 percent of normal delivery could support future population growth, water demand, and development in areas serviced by these priority groups.

Under the No Action, Basic Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach), and Representative Preferred Alternatives, for junior entitlements there are fewer potential futures, and in some cases no potential futures, in which there is any percentage of normal delivery across the first decade of the modeling period. The specific Arizona, California, and Nevada junior entitlements vary by alternative (see **Table TA 17-17**). Under the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives, greater than 80 percent of normal domestic delivery to all junior entitlements occurs in no potential futures, across the first decade of the modeling period. Domestic shortages could manifest as reduced water allocations, delivery restrictions, or the need for additional adaptation and conservation measures, which could

in turn limit the capacity to meet domestic water demand. Reduced capacity to meet domestic water demand could impact existing residents and essential services, constrain planned and future development, and create conveyance or treatment system challenges. The extent of these effects would vary by community based on local water portfolios, infrastructure, regulatory context, conservation achievements, financing capacity, hydrologic conditions, and adaptation feasibility. Further, the shortage distributions applied under these alternatives could result in the complete loss of domestic water for these users. Should shortages result in a reduction or elimination of legal access to municipal water, widespread impacts on social and economic conditions could also be possible. For example, in some scenarios, municipalities could even find the need to pursue alternative water sources, or hauled water if available, as an alternative to support continued services. However, adaptation measures (for example, new supplies, infrastructure, treatment, interconnections, and related financing) can require substantial time and resources and may not be available on the same schedule for all communities. While these specific local project decisions would occur outside the scope of this Final EIS, it is important to note the potential for impacts.

In addition, indirect social costs could occur as a result of a reduction in ecosystem services; also, indirect social costs could occur from reduction of benefits to people provided by the environment. For example, trees in urban areas have been shown to provide high levels of benefits to people in the form of shade, which mitigates urban heat impacts (that is, heat-related illness), local air quality improvements, and enhancement of the visual setting. Should a reduction in domestic water supply result in die-offs of urban and suburban area trees, this could represent a loss of value that would take decades to recapture, due to the growth time required for trees (see, for example, Bloome et al. 2016).

As shown in **Table TA 17-17**, for the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which apply pro rata distribution of shortage, under most modeled futures, would generally allow a larger number of priority groups to receive domestic water deliveries closer to normal conditions. While a pro rata approach would change the distribution of water across all users during shortages, this approach would deviate from the priority-based distribution, resulting in some modeled reductions to domestic deliveries for senior entitlement holders who would otherwise maintain normal domestic delivery under the existing priority system. In contrast, more domestic junior priority water entitlement holders would continue to receive some level of water supply under this approach. In general, the pro rata method would result in more users receiving moderate water deliveries during shortages through a redistribution of water from senior entitlements.

Agricultural Land Use: The alternatives vary in how they distribute irrigation shortages and therefore in their potential to influence long-term land-use patterns. The No Action and Basic Coordination Alternatives rely on priority-based distribution and result in concentrated impacts on junior priority users in Arizona (primarily in Yuma, La Paz and Mohave Counites), with limited mitigation tools. These conditions increase the likelihood of fallowing, crop switching, and economic stress in affected communities. The Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives distribute shortages more broadly across the states and users, reducing concentrated impacts on junior priority holders but introducing greater reductions in California, which could lead to more widespread land-use changes. The Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives incorporate adaptive tools and conservation

reserves, offering potential buffers against extreme shortages; however, their effectiveness depends on stakeholder participation and hydrologic conditions. The Preferred Alternative provides additional flexibility to develop operational guidelines based on conditions. Up to 1.5 maf, the Representative Preferred Alternative for 2027-2028 would result in shortages similar to that under the Maximum Flexibility and the Supply Driven (LB Priority approach) Alternatives, with impacts concentrated on junior users. In the longer term (2029-2060) modeled outcomes under the Representative Preferred Alternative indicate potential for the greatest level of shortage to junior priority users of any alternative. However, based on by the potential 2027-2028 agreements among Lower Division States at the time of publication, the distribution of shortage under any specific operating guidelines adopted under the Preferred Alternative decision framework may differ from the priority distribution method reflected here for the Representative Preferred Alternative; as a result, the potential for fallowing, crop switching, and other associated long term land -use patterns in any given area may vary and impacts may be mitigated in part by agreements that may arise during the development of specific operating guidelines under the Preferred Alternative.

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Technical Appendix 18

Indian Trust Assets

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
ADM	Alternative Distribution Model
afy	acre-feet per year
CAP	Central Arizona Project
CCS	Continued Current Strategies
DMDU	Decision Making under Deep Uncertainty
EIS	Environmental Impact Statement
ICS	intentionally created surplus
ITA	Indian trust asset
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
Lower Basin	Lower Colorado River Basin
maf	million acre-feet
M&I	municipal and industrial
NIA	non-Indian agriculture
PPR	present perfected right
Reclamation	Bureau of Reclamation
SAM	Shortage Allocation Model
U.S.	United States
Upper Basin	Upper Colorado River Basin

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TA 18. Indian Trust Assets

TA 18.1 Affected Environment

The United States (U.S.) has a trust responsibility to tribes as defined by statutes, court decrees, treaties, or other applicable law.[1] Indian trust assets (ITAs) are legal interests in assets held in trust by the federal government for the benefit of federally recognized Native American tribes or individual Native Americans (Reclamation 1994). ITAs can be located on or off established reservation lands and can consist of land or water entitlements[2]; natural resources; monies, such as trust funds; mineral rights; hunting, fishing, trapping, and gathering rights; and other assets. Beneficiaries of the Indian trust relationship are tribes and individual Native Americans; the U.S. is the trustee. ITAs are generally restricted against alienation (that is, they cannot be sold, transferred, abandoned, or lost without approval from the Secretary of the Interior). With federal authority and approval, ITAs may be leased to generate income for tribes or individual Native Americans (Department 2025).

It is the general policy of the Department of the Interior to carry out activities in a manner that protects ITAs and avoids adverse effects whenever possible (Reclamation 1993). In accordance with Bureau of Reclamation (Reclamation) ITA policy and guidance (Reclamation 1994), tribal consultation addressing trust assets should be initiated with appropriate tribal groups and the Bureau of Indian Affairs, and the presence or absence of ITAs should be addressed explicitly in all National Environmental Policy Act documents. Reclamation has consulted with tribes regarding the proposed Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead Environmental Impact Statement (EIS).

TA 18.1.1 Trust Lands

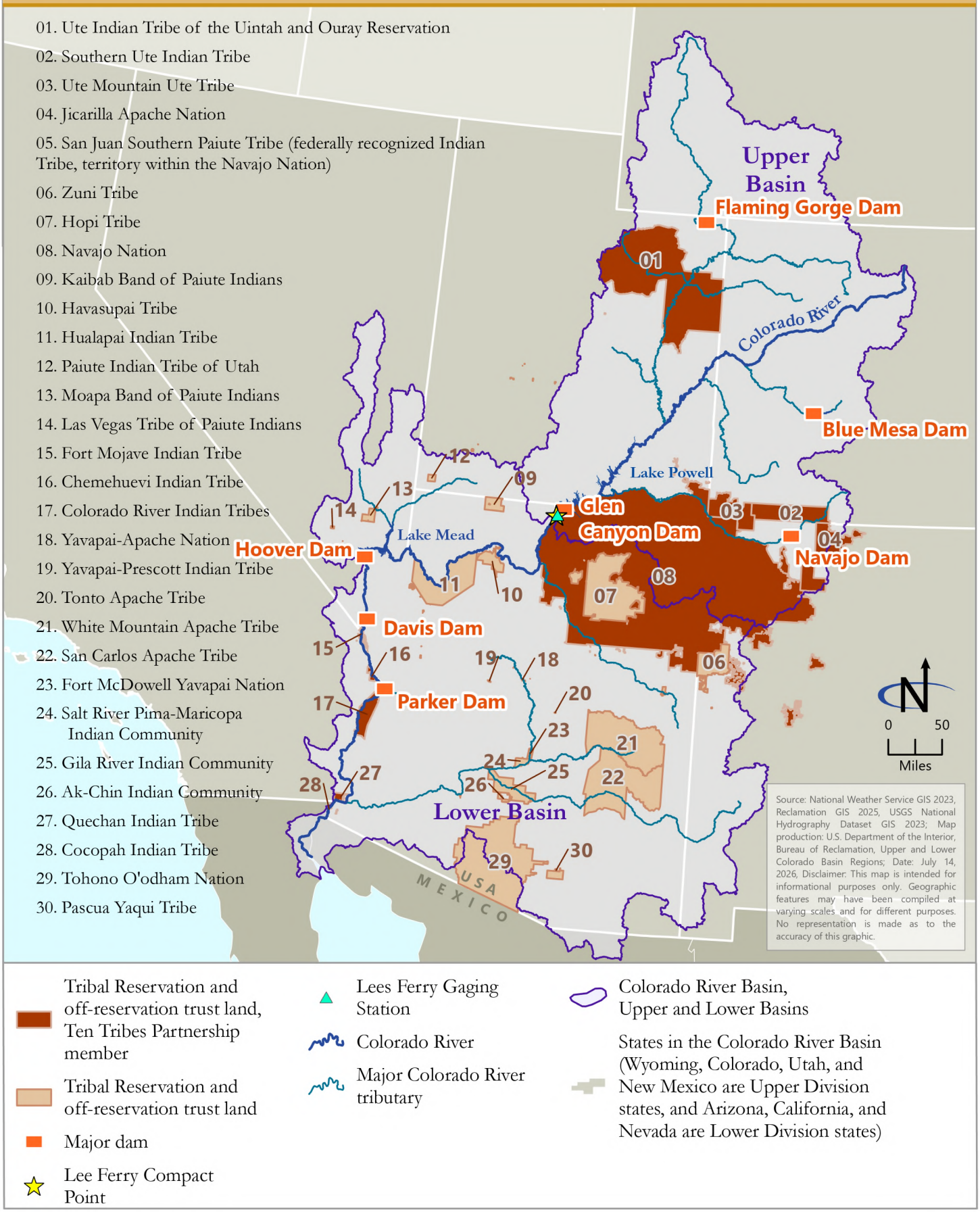
Indian trust lands are lands that the U.S. holds in trust for the benefit of a tribe (tribal trust land) or for an individual Native American (individual trust land). Trust lands may be located on or off a reservation. While reservations are not always synonymous with trust lands, the exterior boundaries of reservations are used to define the trust land assets for purposes of this National Environmental Policy Act analysis, to be inclusive. There are 30 federally recognized tribes in the Colorado River Basin; of these, 29 have established reservations (**Map TA 18-1**). The San Juan Southern Paiute Tribe does not have its own reservation. Tribal land uses include, but are not limited to, communal and spiritual uses, domestic use, and agriculture and economic development.

[1] Nothing in this technical appendix is intended to modify, abrogate, or create ITAs. Any particular ITA remains defined by and subject to applicable authority.

[2] Rights and entitlements may be used interchangeably in this technical appendix for simplicity, and no legal change to any ITA is intended.

— BUREAU OF —
RECLAMATION

Map TA 18-1
Tribes and Reservations within the Colorado River Basin



Native American reservations in the U.S. were created and modified through a complex history of statutes, treaties, executive orders, agreements, and federal policies (BIA 2025a). The Indian Removal Act of 1830 resulted in the forced removal of tribes from their ancestral lands east of the Mississippi River into the Western U.S. Lands inhabited by these relocated groups came to be known as "Indian territory", which served as the precursor to federal reservations (BIA 2025a). The Indian Appropriations Act of 1851 resulted in further confinement of Native Americans to areas called "reservations" (Elliott 2025). The General Allotment Act (also known as the Dawes Act) of 1887 divided communal reservation lands into trust land allotted to individual Native Americans and their families (BIA 2025a). It also opened non-allotted land to non-tribal ownership, resulting in significant fractionalization and loss of tribal-controlled land (BIA 2025a). In the twentieth and twenty-first centuries, federal policies have attempted to help restore the self-determination of Native American tribes and reduce the effects of reservation fractionalization (BIA 2025a, 2025b). See the Tribal Treaties Database (OSU 2025) for detailed information on treaties, agreements, and executive orders.

Upper Basin

From approximately Northeast to Southeast, the Upper Colorado River Basin (Upper Basin) reservations include those associated with the Ute Indian Tribe of the Uintah and Ouray Reservation (Utah), the Southern Ute Indian Tribe (Colorado), the Ute Mountain Ute Tribe (Colorado, New Mexico, Utah), the Jicarilla Apache Nation (New Mexico), and the Navajo Nation (Arizona, New Mexico, Utah).

Lower Basin

From approximately Northeast to Southeast, Lower Colorado River Basin (Lower Basin) reservations include those associated with the Zuni Tribe (Arizona, New Mexico), the Navajo Nation (Arizona, New Mexico, Utah), the Hopi Tribe (Arizona), the Kaibab Band of Paiute Indians (Arizona), the Havasupai Tribe (Arizona), the Hualapai Indian Tribe (Arizona), the Shivwits Band of Paiute Indian Tribe (Utah), the Moapa Band of Paiute Indians (Nevada), the Las Vegas Tribe of Paiute Indians (Nevada), the Fort Mojave Indian Tribe (Arizona, California, Nevada), the Chemehuevi Indian Tribe (California), the Colorado Indian River Tribes (Arizona, California),[3] the Yavapai-Apache Nation (Arizona), the Yavapai-Prescott Indian Tribe (Arizona), the Tonto Apache Tribe (Arizona), the White Mountain Apache Tribe (Arizona), the San Carlos Apache Tribe (Arizona), the Fort McDowell Yavapai Nation (Arizona), the Salt River Pima-Maricopa Indian Community (Arizona), the Gila River Indian Community (Arizona), the Ak-Chin Indian Community (Arizona), the Fort Yuma Quechan Indian Tribe (Arizona, California), the Cocopah Indian Tribe (Arizona), the Tohono O'odham Nation (Arizona), and the Pascua Yaqui Tribe (Arizona).

In addition, trust land includes the Fort Mojave off-reservation trust land in San Bernardino County, California. No other off-reservation trust land along the mainstream Colorado River has been identified.

[3] Colorado River Indian Tribes is comprised of members of four distinct tribes: the Mohave, Chemehuevi, Hopi, and Navajo.

TA 18.1.2 Water Entitlements, Water Deliveries, and Storage and Conservation Options

The management and operation of the Colorado River and delivery of its waters to various users is governed by a complex set of treaties, statutes, Supreme Court decrees, and other settlements and agreements collectively known as the "Law of the River". In general terms, the Law of the River establishes a priority system for the distribution of available water. Higher priority (senior) water entitlements are filled first, and lower priority (junior) entitlements are filled next. Some tribal water entitlements have higher priorities and others are lower priorities. **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation, provides more detail on the priority of each tribal water entitlement in the Lower Basin.

TA 4, Water Deliveries, provides more detail on the Law of the River. This appendix includes tables of tribal mainstream Colorado River water entitlements and Central Arizona Project (CAP) contracts.[4] The entitlements included in this analysis are consistent with those in the Shortage Allocation Models (SAMs) and Alternative Distribution Models (ADMs; see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation) and other sections of the Final EIS.[5]

Upper Basin

Water Entitlements

The five Upper Basin Tribes draw from various tributaries to the Colorado River (**Table TA 18-1**).

Table TA 18-1
Upper Basin Native American Water Rights

Tribe or Reservation	Basin	Diversion Right (Acre-feet per year [afy])	Depletion Right (afy)
Jicarilla Apache Nation	San Juan River	45,683	34,195
Navajo Nation	San Juan River	633,531	336,979
Navajo Nation	State of Utah		81,500
Southern Ute Indian Tribe	San Juan, Piedra, Pine, Florida, Animas, La Plata, and Mancos	137,090	74,138
Ute Indian Tribe of the Uintah and Ouray Reservation	Duchesne, Lake Fork, Yellowstone, Uinta, Whiterocks, White, and Green Rivers; Bitter, Sweet Water, Willow, and Hill Creeks	480,594	258,943
Ute Mountain Ute Tribe	San Juan, Animas, La Plata, Mancos, McElmo, and Dolores Rivers	88,358	51,081

Source: Reclamation 2012

[4] While some entitlements are not ITAs, they are included for reference in this Appendix.
[5] Tribes may have other sources of water, including groundwater and other surface water, which are not part of this analysis.

Lower Basin

Water Entitlements

Lower Basin Tribes have mainstream Colorado River water entitlements as determined and quantified under the 2006 Consolidated Decree, and water entitlements and settlements, including CAP water.

Water Entitlements Determined under Arizona v. California

The Consolidated Decree determined and quantified mainstream Colorado River water rights for five tribes— Chemehuevi Indian Tribe (Chemehuevi Indian Reservation of California), Colorado River Indian Tribes (Colorado River Indian Reservation of Arizona and California), Fort Mojave Indian Tribe (Fort Mojave Indian Reservation of Arizona, California, and Nevada), Fort Yuma Quechan Indian Tribe (Fort Yuma Indian Reservation of Arizona and California), and Cocopah Indian Tribe (Cocopah Indian Reservation of Arizona) water entitlements.

Table TA 18-2 summarizes water entitlements along the Colorado mainstream in the Lower Basin.

Table TA 18-2
Colorado River Mainstream Native American Water Entitlements

Tribe/Reservation	State	Entitlement (afy of Diversion)	Present Perfected Right (PPR) Number	Priority within State	Priority Date
Chemehuevi Reservation	CA	11,340	22	PPR	February 2, 1907
Cocopah Indian Reservation	AZ	1,140	8	1	1915
Cocopah Indian Reservation	AZ	7,681	1	1	September 27, 1917
Cocopah Indian Reservation	AZ	2,026	N/A	4	June 24, 1974
Cocopah Indian Reservation	*AZ subtotal*	*10,847*	*N/A*	*N/A*	*N/A*
Colorado River Indian Reservation	AZ	358,400	2	1	March 3, 1865
Colorado River Indian Reservation	AZ	252,016	2	1	November 22, 1873
Colorado River Indian Reservation	AZ	51,986	2	1	November 16, 1874
Colorado River Indian Reservation	*AZ subtotal*	*662,402*	*N/A*	*N/A*	*N/A*
Colorado River Indian Reservation	CA	10,745	24	PPR	November 22, 1873
Colorado River Indian Reservation	CA	40,241	24	PPR	November 16, 1874
Colorado River Indian Reservation	CA	5,860	24	PPR	May 15, 1876

Tribe/Reservation	State	Entitlement (afy of Diversion)	Present Perfected Right (PPR) Number	Priority within State	Priority Date
Colorado River Indian Reservation	*CA subtotal*	*56,846*	*N/A*	*N/A*	*N/A*
Colorado River Indian Reservation	*AZ and CA total*	*719,248*	*N/A*	*N/A*	*N/A*
Fort Mojave Reservation	AZ	103,535	3	1	1890, 1911
Fort Mojave Reservation	CA	16,720	25	PPR	September 18, 1890
Fort Mojave Reservation	NV	12,534	81	1	September 18, 1890
Fort Mojave Reservation	*CA and NV total*	*132,789*	*N/A*	*N/A*	*N/A*
Fort Yuma (Quechan) Indian Reservation	AZ	6,350	3a	1	January 9, 1884
Fort Yuma (Quechan) Indian Reservation	CA	71,616	23	PPR	January 9, 1884
Fort Yuma (Quechan) Indian Reservation subtotal	*AZ and CA total*	*77,966*	*N/A*	*N/A*	*N/A*
Hopi Tribe[+]	AZ	4,278	N/A	4	January 31, 1983
Hopi Tribe[+]	AZ	500	N/A	5	January 31, 1983
Hopi Tribe[+]	AZ	1,000	N/A	6	January 31, 1983
Hopi Tribe subtotal[+]	*AZ*	*5,778*	*N/A*	*N/A*	*N/A*
Hualapai Tribe[+]	*AZ*	*1,110*	*N/A*	*4*	*February 17, 2006*

Source: Reclamation 2012

[+] Indicates that the entitlement is not an ITA.

Notes: Arizona (AZ); California (CA); Nevada (NV)

Notes: The diversionary entitlements, including equivalents, are listed for comparative analysis purposes, which is not intended to modify the entitlement as defined by the applicable establishing authority.

Central Arizona Project

Several tribes in Arizona hold CAP water entitlements, which may be held in trust in accordance with the applicable settlement. These tribal entitlements to CAP water or Colorado River water delivered through the CAP in central Arizona are administered pursuant to settlements and water delivery contracts between tribes and the Secretary of the Interior (**Table TA 18-3**).

Table TA 18-3
CAP Water Delivery Entitlements

Tribe or Reservation	Contract Delivery Volume (afy)	Arizona Priority	CAP Priority
Ak-Chin Community	50,000	3	N/A
Ak-Chin Community	58,300	4	Indian
Ak-Chin Community	10,000	Additional water	N/A
Ak-Chin subtotal	*72,000 to 85,000*[6]	*N/A*	*N/A*
Fort McDowell Yavapai Nation	18,233	4	Indian
Gila River Indian Community	191,200	4	Indian
Gila River Indian Community	120,600	4	Non-Indian Agriculture
Gila River Indian Community subtotal	*311,800*	*N/A*	*N/A*
Hualapai Tribe	4,000	4	Non-Indian Agriculture
Pascua Yaqui Tribe+	500	4	Indian
Salt River Pima-Maricopa Indian Community[7]	13,300	4	Indian
San Carlos Apache Tribe	12,700	4	Indian
San Carlos Apache Tribe	18,145	4	Municipal & Industrial
San Carlos Reservation subtotal	*30,845*[8]	*N/A*	*N/A*
Tohono O'odham Nation – San Xavier District	27,000	4	Indian
Tohono O'odham Nation – San Xavier District	23,000	4	Non-Indian Agriculture
Tohono O'odham Nation – Schuk Toak District	10,800	4	Indian
Tohono O'odham Nation – Schuk Toak District	5,200	4	Non-Indian Agriculture
Tohono O'odham Nation – Sif Oidak District+	8,000	4	Indian
Tohono O'odham Nation subtotal	*74,000*	*N/A*	*N/A*
Tonto Apache Tribe+	128	4	Indian
White Mountain Apache Tribe	23,782	4	Non-Indian Agriculture

[6] The U.S. delivers between 72,000 to 85,000 afy to the Ak-Chin Indian Community in accordance with the terms of its settlement, even though Ak-Chin's total entitlement is greater than this amount. The San Carlos Apache Tribe is entitled to the CAP Indian Priority water not required for delivery to the Ak-Chin Indian Community, consistent with the terms of its settlement.

[7] Other supplies are not listed in this appendix.

[8] In addition, the San Carlos Apache Tribe is entitled to the Ak-Chin Community's CAP Indian Priority water not required for delivery to the Ak-Chin Indian Community, consistent with the terms of its settlement.

Tribe or Reservation	Contract Delivery Volume (afy)	Arizona Priority	CAP Priority
White Mountain Apache Tribe	1,218	4	Indian
White Mountain Apache Tribe subtotal	*25,000*	*N/A*	*N/A*
Yavapai-Apache Nation[+]	1,200	4	Indian

Source: Reclamation 2012; CAP 2025

[+] Indicates that the entitlement is not an ITA.

Unquantified and Undeveloped Water Rights

In the context of tribal water, unquantified water rights refer to federally reserved water rights that have not yet been determined and quantified through an adjudication or settlement. While recognizing this important issue, the water deliveries analysis only considers quantified tribal water rights. This analysis should not be construed to, in any way, preclude or limit any ongoing or future quantification of tribal water rights.

In the context of tribal water, undeveloped water rights refer to quantified rights that are not being fully utilized. Undeveloped water may be due to a lack of the infrastructure needed to divert, transport, and/or use water (Water and Tribes Initiative 2025). While recognizing this important issue, this analysis does not distinguish between developed and undeveloped rights in the water deliveries analysis. This analysis should not be construed to, in any way, preclude or limit any ongoing or future tribal development of water rights.

TA 18.1.3 Other Indian Trust Assets

ITAs can also include hunting, fishing, trapping, and gathering rights; mineral rights; and cultural, biological, and other resources. Whether or not specific rights or resources legally qualify as an ITA is complicated and depends on multiple factors, such as land status (Reclamation 1994). Reclamation consulted with tribes and the Bureau of Indian Affairs to identify ITAs. To date, potential changes in water deliveries and activities affected by potential changes in water deliveries (e.g., irrigated agriculture) have been the primary concerns related to ITAs.

Reclamation acknowledges that the 30 Basin Tribes depend on the Colorado River and its tributaries for a variety of purposes, including cultural and spiritual activities, wildlife, instream flows, recreation, and other purposes. See **TA 13**, Tribal Resources, and **TA 11**, Cultural Resources, for analysis of tribal and cultural resources, respectively. In general, those analyses apply to tribal and cultural resources that qualify as ITAs.

Although income derived from ITAs is not an ITA, Reclamation notes that income derived from ITAs such as agricultural products, water leases, and fees charged for outdoor recreation on tribal land can be an important source of income for tribes.

TA 18.2 Environmental Consequences

Following Reclamation ITA policy (Reclamation 1994), the following analysis discusses actions that affect the value, use, or enjoyment of ITAs.

TA 18.2.1 Methodology

The methodology varies for each type of ITA. Quantitative metrics are analyzed where possible; otherwise, qualitative discussion is provided.

- For trust lands, potential changes in irrigated acreage due to fluctuating water deliveries are a primary concern. The amount of tribal agricultural land (in acres) estimated to be fallowed under each alternative is presented.
- For water entitlements, the analysis focuses on changes in the quantity of water (in acre-feet) estimated to be delivered to tribes under each alternative. Changes in options to conserve and store water are also discussed.
- For other ITAs, analysis is qualitative.

Impact Analysis Area

The impact analysis area includes land within the boundaries of reservations and off-reservation trust land within the Colorado River Basin (29 reservations listed in **TA 18.1**[9]).

Assumptions

- Trust land includes land within the borders of established reservations and off-reservation trust land.
- For the water deliveries analysis, the assumptions of Colorado River Simulation System modeling (**Appendix A**, CRSS Model Documentation) and SAM modeling (**Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation) apply.
- For potential impacts on agricultural land, the assumptions of the agricultural modeling apply (see **TA 16**, Socioeconomics, for more details).

Impact Indicators

- Percent of normal water entitlement delivered to Upper and Lower Basin Tribes.
- Changes in acres of irrigated tribal agricultural land.

TA 18.2.2 Issue 1: How Will Changes in Dam Operations Affect Tribal Water Entitlements, Water Deliveries, and Water Storage and Conservation Options?

The approaches to distributing shortages incorporated in all alternatives are designed to explore a wide range of potential concepts and impacts; they do not reflect an intention by Reclamation to alter apportionments or water entitlements. However, because the concepts would affect a range of

[9] As discussed in **Section TA 18.1**, one of the 30 Basin Tribes does not have an established reservation; therefore, there are 29 reservations.

users, impacts on deliveries to different entities are analyzed, and addressed in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

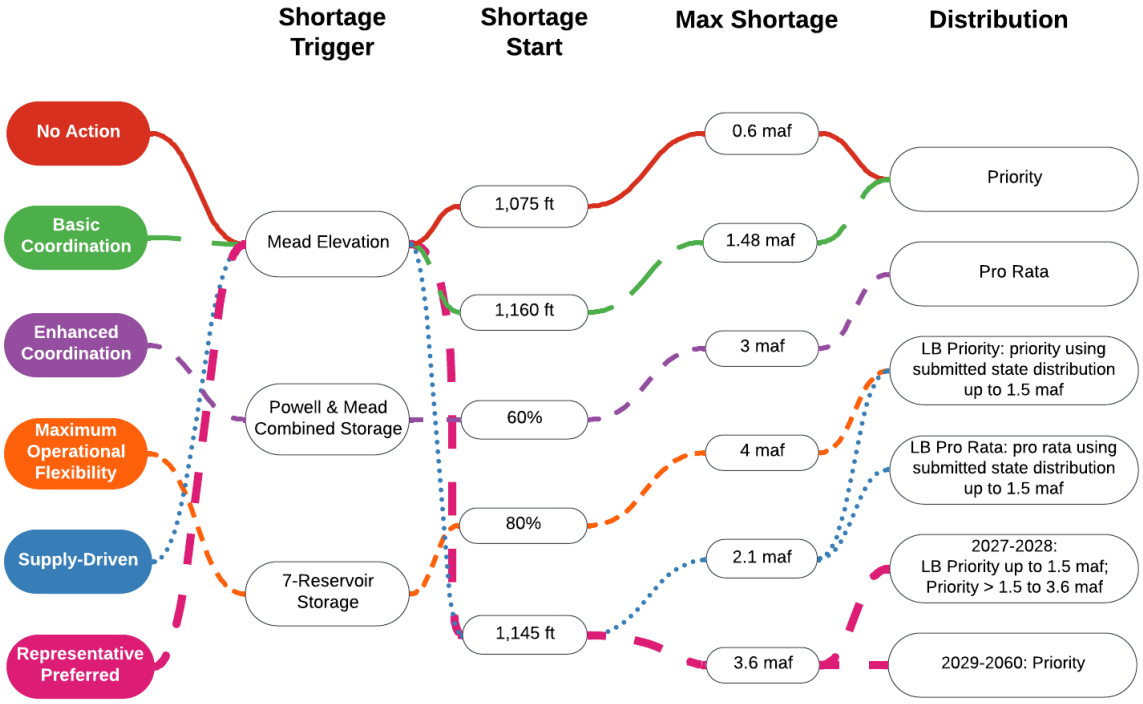
With respect to potential tribal water deliveries, the alternatives can be distinguished based on the following characteristics:

- The maximum shortage, which affects the relative frequency and severity of Lower Basin water shortages, including potential dead pool–related reductions (that is, releases reduced by low Lake Mead levels or outlet limits).
- The approach used to distribute Lower Basin water under shortages[10].
    - The Priority distribution approach distributes shortages based on existing statutory, case law, and contractual provisions. It is used in the Continued Current Strategies (CCS) Comparative Baseline, the No Action Alternative, and the Basic Coordination Alternative. It is also used in the Preferred Alternative when no consensus distribution agreements exist that would alter the approach. Note that Reclamation and stakeholders would remain able to adopt consensus shortage distributions during the term of the Preferred Alternative.
    - The Pro Rata distribution approach distributes shortages pro rata (that is, in a determined proportion) across water users. It is used in the Enhanced Coordination Alternative.
    - The Lower Basin Priority (LB Priority) distribution approach follows specified state-specific distributions for the first 1.5 million acre-feet (maf) of shortage and then follows priority for larger shortages. It is used in the Maximum Operational Flexibility and the Supply Driven (LB Priority approach) Alternatives.
    - The Lower Basin Pro Rata (LB Pro Rata) approach follows specified state-specific distributions for the first 1.5 maf of shortage and then follows pro rata for larger shortages. It is used in the Supply Driven Alternative (LB Pro Rata approach).
- Options for tribes and other water users to conserve and store water in Lake Powell or Lake Mead.

Figure TA 18-1 and **Table TA 18-4** summarize the alternatives based on these characteristics. **Figure TA 18-1** provides summary information on the shortage triggering metric, when shortages start relative to that metric, maximum operational shortage volume, and modeled distribution method. **Table TA 18-4** provides information on the maximum shortage volume, distribution method, and water storage and conservation options. **Table TA 18-4** includes the CCS Comparative Baseline for comparison. See **Chapter 2**, Description of Alternatives, and **Appendix S**, Additional Description of Alternatives, for a more detailed discussion of the alternatives.

[10] See **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation, for more information on the distribution methods.

Figure TA 18-1
Lower Basin Shortage Guidelines



Notes: Additional restrictions in water deliveries will occur when Lake Mead is near dead pool, resulting in large reductions (referred to as "dead pool-related reductions"). These are not considered an operational element of the alternatives. The "Representative Preferred Alternative" is a set of modeling assumptions designed around the Preferred Alternative sideboards. The specific operating guidelines for each operating interval during the term of the Preferred Alternative may differ. Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table TA 18-4
Comparison of Key Factors Affecting Tribal Water Deliveries among Alternatives and the CCS Comparative Baseline

Scenario	Maximum Shortage (maf)[b]	Distribution Method	Water Storage and Conservation Options
CCS Comparative Baseline	1.375[a]	Priority	Continued intentionally created surplus (ICS). No new mechanisms.
No Action Alternative	0.6	Priority	Water conserved under previous mechanisms that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. No new mechanisms.

Scenario	Maximum Shortage (maf)[b]	Distribution Method	Water Storage and Conservation Options
Preferred Alternative (Including Representation of Operational Elements)	3.6	In 2027-2028, shortages up to 1.5 maf are distributed based on LB Priority and shortages exceeding 1.5 maf are distributed based on priority. After 2028, shortages are distributed based on priority.	Yes, three new mechanisms in place of ICS (one conservation pool in Lake Powell and two in Lake Mead)
Basic Coordination Alternative	1.48	Priority	Water conserved under previous mechanisms that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. No new mechanisms.
Enhanced Coordination Alternative	3.0	Pro rata	Yes, three new mechanisms in place of ICS (one conservation pool in Lake Powell and two in Lake Mead)
Maximum Operational Flexibility Alternative	4.0	LB Priority	Yes, one new mechanism in place of ICS (a combined Lake Powell and Lake Mead conservation pool)
Supply Driven Alternative (LB Priority approach)	2.1	LB Priority	Yes, two new mechanisms in place of ICS (one conservation pool in Lake Powell and one in Lake Mead)
Supply Driven Alternative (LB Pro Rata approach)	2.1	LB Pro Rata	Yes, two new mechanisms in place of ICS (one conservation pool in Lake Powell and one in Lake Mead)

Source: **Chapter 2**, Description of Alternatives, **Appendix S**, Additional Description of Alternatives

[a] Includes the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead, Minute 323 Bi-national Water Scarcity Contingency Plan, and Drought Contingency Plans.

[b] Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico. The U.S. will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Upper Basin

Water Deliveries

None of the alternatives would directly or indirectly affect Upper Basin tribal water entitlements. As discussed below, water storage and conservation mechanisms under some alternatives could indirectly affect the amount of stored conservation water available to Upper Basin Tribes.

Storage and Conservation Options

The No Action and Basic Coordination Alternatives have no new water storage mechanisms and would not affect water storage and conservation by Upper Basin Tribes. The other four alternatives do have new storage and conservation mechanisms, which are summarized below. See **Chapter 2** for a full description of these mechanisms and how they would operate. Note that in all cases, stored water would be available for water transactions with other Upper Basin water users, both within and across Upper Division States.

- Under the Preferred Alternative, up to 3.0 maf of water conserved by Upper Basin water users could be stored in Lake Powell. Upper Basin Tribes would receive credit for the contribution of conserved consumptive use stored in the pool. Under certain conditions, water in the pool could be released.
- Under the Enhanced Coordination Alternative, up to 2.0 maf of water conserved by Upper Basin water users could be stored in Lake Powell. Under certain conditions, the stored water would be made available to offset portions of Lower Basin shortages, thereby reducing the amount of stored water available to Upper Basin Tribes that have participated in the mechanism.
- Under the Maximum Operational Flexibility Alternative, up to 3.0 maf of water conserved by Upper Basin water users could be stored in a combined pool managed across both Lake Powell and Lake Mead. Under certain conditions, stored water could be converted to system water, thereby reducing the amount of stored water available to Upper Basin Tribes that have participated in the mechanism.
- Under the Supply Driven Alternative, Upper Basin water users could contribute up to 3.0 maf of water to a storage pool in Lake Powell. Water in the pool could be released if needed to meet the determined water-year volume, thereby reducing the amount of stored water available to Upper Basin Tribes that have participated in the mechanism.

In general, the four alternatives above that include new mechanisms for storage and conservation of water would provide additional options to Upper Basin Tribes. Assuming these methods could be implemented with appropriate authority, first, the mechanisms would allow tribes to store water as insurance against potential future changes in water demand or supply. Second, the mechanisms would create a new way for tribes to lease or transfer water from or to other Upper Basin water users.

Lower Basin

Water Deliveries

Some alternatives impact Lower Basin tribal entitlements by altering the shortage distribution methodologies. The alternatives also impact water deliveries to some degree. Reclamation modeled water deliveries in the Lower Basin using the SAM and ADM. There are three unique SAMs and five ADMs to capture the nuances of the alternatives and sensitivity analyses, which are further explained in **Appendix S**, Additional Description of Alternatives.

In this analysis, three main factors combine to determine potential Lower Basin tribal water deliveries in any given year:[11]

1. The severity of potential shortages
2. The distribution method used to allocate water under shortages
3. The frequency of dead pool–related reductions[12]

This analysis focuses on the first two factors. The third factor, dead pool–related reductions, is not a focus of this analysis.[13] In general, Reclamation anticipates acting to minimize dead pool–related reductions. However, the methods for doing so and the methods for allocating water under a dead pool–related release are unknown and too speculative to be included in this Final EIS.

Figure TA 18-2 illustrates how the percentage of water delivery changes as shortages become more severe. There are four tables in **Figure TA 18-2**, one for each of the different distribution methods included in the alternatives. For the purposes of this analysis, tribes are aggregated into four groups based on entitlement priorities, which are contained in the rows of **Figure TA 18-2**:[14] Shortage impacts for specific entities are contained in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

- The "AZ CAP NIA" group are the most junior entitlements and includes tribes with Arizona CAP non-Indian agriculture (NIA)-A and NIA-B priorities. This group consists of four tribes with contracts totaling approximately 177,000 acre-feet per year (afy).
- The "AZ CAP Indian, CAP municipal and industrial (M&I), AZ 4i" group includes tribes with Arizona CAP Indian, CAP Municipal & Industrial, and Arizona 4i priorities. This group consists of 13 tribes and 16 individual entitlements (including mainstream water reserved for future settlement and unallocated) totaling approximately 374,000 afy.
- The "AZ 3" includes one tribe with Arizona 3rd priority, totaling 50,000 afy.
- The present perfected right (PPR) group are the most senior entitlements; this group includes five tribes in all three Lower Division States. Five tribes with 15 discretely quantified entitlements totaling approximately 503,000 afy are included in this group.

The columns in **Figure TA 18-2** represent different total Lower Basin shortage levels. The cells in **Figure TA 18-2** show the percentage delivery of water entitlements for each group. Note that the cells in **Figure TA 18-2** are combined results for each group, not for any single tribe within a group; therefore, the data for individual tribes within a group may differ from the group's data. Similar information on potential deliveries for individual tribes is presented in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

[11] The phrase "potential water deliveries" is intended to recognize that some tribal entitlements are not fully developed and/or utilized. For simplicity, this analysis assumes that water deliveries and entitlements refer to the same quantities of water.
[12] Conditions that might cause a dead pool–related release are described in **TA 4**, Water Deliveries.
[13] Modeling results related to the potential frequency of dead pool–related releases are discussed further below.
[14] The number of tribes, water entitlements, and amounts listed below come from the SAM (see **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation, for modeling assumptions and descriptions of priority nomenclature).

Figure TA 18-2
Comparison of Water Deliveries by Distribution Method, Tribal Priority Group, and Shortage Amount

Percent Delivery by Total Shortage Volume (maf) under the Priority Distribution Method (Used in No Action, Basic Coordination, and Representative Preferred [2029-2060] Alternatives)

Tribal Priority Group	0.0	0.2	0.4	0.6	0.8	1.0	1.5	3.0	4.0	5.0	6.0	7.0
AZ CAP NIA	100.0	39.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AZ CAP Indian, CAP M&I, AZ 4i	100.0	100.0	95.5	82.7	68.0	53.3	16.5	0.0	0.0	0.0	0.0	0.0
AZ 3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	66.2	31.5	0.0	0.0	0.0
PPR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Percent Delivery by Total Shortage Volume (maf) under the Pro Rata Distribution Method (Used in Enhanced Coordination Alternative)

Tribal Priority Group	0.0	0.2	0.4	0.6	0.8	1.0	1.5	3.0	4.0	5.0	6.0	7.0
AZ CAP NIA	100.0	97.8	95.5	93.3	91.1	88.8	83.2	66.5	55.3	44.1	33.0	21.8
AZ CAP Indian, CAP M&I, AZ 4i	100.0	97.8	95.5	93.3	91.1	88.8	83.2	66.5	55.3	44.1	33.0	21.8
AZ 3	100.0	97.8	95.5	93.3	91.1	88.8	83.2	66.5	55.3	44.1	33.0	21.8
PPR	100.0	97.8	95.5	93.3	91.1	88.8	83.3	66.5	55.4	44.2	33.1	21.9

Percent Delivery by Total Shortage Volume (maf) under the State-Specific up to 1.5 maf, then Priority Distribution Method (Used in the Maximum Operational Flexibility, Supply Driven [LB Priority approach], and Representative Preferred [2027-2028] Alternatives)

Tribal Priority Group	0.0	0.2	0.4	0.6	0.8	1.0	1.5	3.0	4.0	5.0	6.0	7.0
AZ CAP NIA	100.0	37.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AZ CAP Indian, CAP M&I, AZ 4i	100.0	100.0	97.5	91.3	83.5	75.2	54.6	0.0	0.0	0.0	0.0	0.0
AZ 3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	79.8	38.1	0.0	0.0	0.0
PPR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Percent Delivery by Total Shortage Volume (maf) under the State-Specific up to 1.5 maf, then Pro Rata Distribution Method (Used in the Supply Driven [LB Pro Rata Distribution approach] Alternative)

Tribal Priority Group	0.0	0.2	0.4	0.6	0.8	1.0	1.5	3.0	4.0	5.0	6.0	7.0
AZ CAP NIA	100.0	94.3	89.9	86.8	83.7	80.6	72.9	58.3	48.6	38.9	29.1	19.4
AZ CAP Indian, CAP M&I, AZ 4i	100.0	94.3	89.9	86.8	83.7	80.6	72.9	58.3	48.6	38.9	29.1	19.4
AZ 3	100.0	94.3	89.9	86.8	83.7	80.6	72.9	58.3	48.6	38.9	29.1	19.4
PPR	100.0	95.3	91.5	88.7	85.9	83.0	75.9	60.7	50.6	40.5	30.4	20.2

Source: SAMs and ADMs.

It is important to note that the shortages depicted in **Figure TA 18-2** extend beyond the maximum shortages specified in the alternatives, which range from 0.6 maf to 4.0 maf (**Table TA 18-4**). The inclusion of larger shortages in **Figure TA 18-2** should not be taken to imply that these specific distributions would, in fact, apply to shortages higher than the maximum shortages (such as might happen during a dead pool–related release); rather, it is intended to better illustrate the implications of the different distribution methods. Please refer to the maximum shortages in **Table TA 18-4** when interpreting the information in **Figure TA 18-2**.

In **Figure TA 18-2**, the different influences that the priority and pro rata distribution methods (the first two tables) have on the percentage delivery of water are readily apparent. Under the priority distribution system, less water is delivered to groups with more junior water entitlements, and more water is delivered to groups with more senior water entitlements. The differences in the percentage of water delivered increase as the shortage volume increases. In contrast, the percentage of water delivered under the pro rata distribution method is the same across the groups for all levels of shortages.

The third table shows the LB Priority distribution approach (that is, state-specific percentages up to 1.5 maf of shortage, then the priority distribution method for larger shortages). It results in similar deliveries as the priority distribution for all priority groups except the AZ CAP Indian, CAP M&I, AZ4 group. This group receives more water under shortages up to 1.5 maf than the straight priority distribution method.

The fourth table shows the LB Pro Rata distribution approach (that is, state-specific percentages up to 1.5 maf, then the pro rata distribution method for larger shortages). It has a similar pattern to the pro rata distribution (the second table) but has differences in the specific numbers in each cell. Like the pro rata distribution, the LB Pro Rata distribution approach delivers more water to junior water entitlements holders and less water to senior water entitlements holders, compared to the priority distribution methods.

Decision Making under Deep Uncertainty (DMDU) is an approach used to expand on the quantitative analysis. It is a non-probabilistic evaluation framework that compares alternatives based on their ability to meet specific performance criteria in many potential future conditions and analyzes how the alternatives respond to specific hydrologic conditions. Additional background and technical details about the DMDU framework are provided in **Appendix E**, DMDU Overview and Approach.

DMDU analysis expands the above analysis by integrating information on the percentage of futures in which different amounts of shortages are estimated to occur under the different alternatives. For tribal water deliveries, deliveries of 20 percent, 40 percent, 60 percent, and 80 percent of normal deliveries are modeled. As explained further below, the results show the percentage of futures in which these thresholds are met in 90 percent or more of the years within each modeled future.

The DMDU figures are presented in **Figure TA 18-3** through **Figure TA 18-11**. The rows contain different percentages of normal water deliveries, where "normal" means under non-Shortage Conditions. The top row contains the highest modeled level of water delivery (80 percent of normal

deliveries), which is the hardest threshold to achieve. The columns contain the CCS Comparative Baseline, the No Action Alternative, and the action alternatives.

Cells are color-coded to indicate the percentage of modeled futures in which water deliveries exceed the thresholds in the row headers in at least 90 percent of the years of a future. The row indicating water deliveries of at least 80 percent of normal deliveries (the top row) has a purple border. Solely for the purposes of considering vulnerability within the DMDU modeling framework, a "preferred minimum performance" outcome is defined as a future trace in which at least 80 percent of normal water deliveries is estimated to be delivered in at least 90 percent of the years in a modeled future. In contrast, an "undesirable performance" future means that the preferred minimum performance criteria are not met. The 80 percent threshold was chosen as the "preferred minimum performance" because it is the model outcome with the largest quantity of water delivered.[15] Within the purple-bordered row, the percentage of futures that meet the preferred criteria is presented.

Note that the non-gray cells (that is, those except the bottom row) in the DMDU figures present the percentage of futures associated with shortages only. A shortage is prescribed by each alternative. Another type of reduction in water delivery results from a dead pool–related release, which occurs when conditions do not support unconstrained releases.[16] Different shortage volumes under the different alternatives affect the frequency of dead pool–related reductions.[17] The percentage of futures in which dead pool–related reductions occur under each alternative is presented in the gray cells at the bottom of the DMDU figures.

The DMDU figures are discussed below, in order of the priority groups with the most senior water entitlements to the group with the most junior entitlements. Note that the DMDU analysis is summarized at the end of this section. The following points are helpful when interpreting DMDU results for the Representative Preferred Alternative:

- There is an important distinction between the Preferred Alternative and the *Representative* Preferred Alternative. As discussed in **Chapter 2**, the Preferred Alternative is a multi-year decision framework that establishes the process and criteria that would govern development and adoption of operating guidelines through 2036. The decision framework is anticipated to be implemented in two-year operating intervals. Unlike other alternatives, the operating guidelines for each interval are not specified in this Final EIS. The sideboards provide a basis for assumptions included in the Representative Preferred Alternative which captures the range of operating guidelines that may be adopted during each interval, but exact operations would be subject to the guidelines in place during each interval.

- The Preferred Alternative has a defined implementation timeframe of 10 years; however, the Representative Preferred Alternative is compared to the other alternatives for the entire modeling horizon of 34 years to enable comparison of potential long-term impacts.

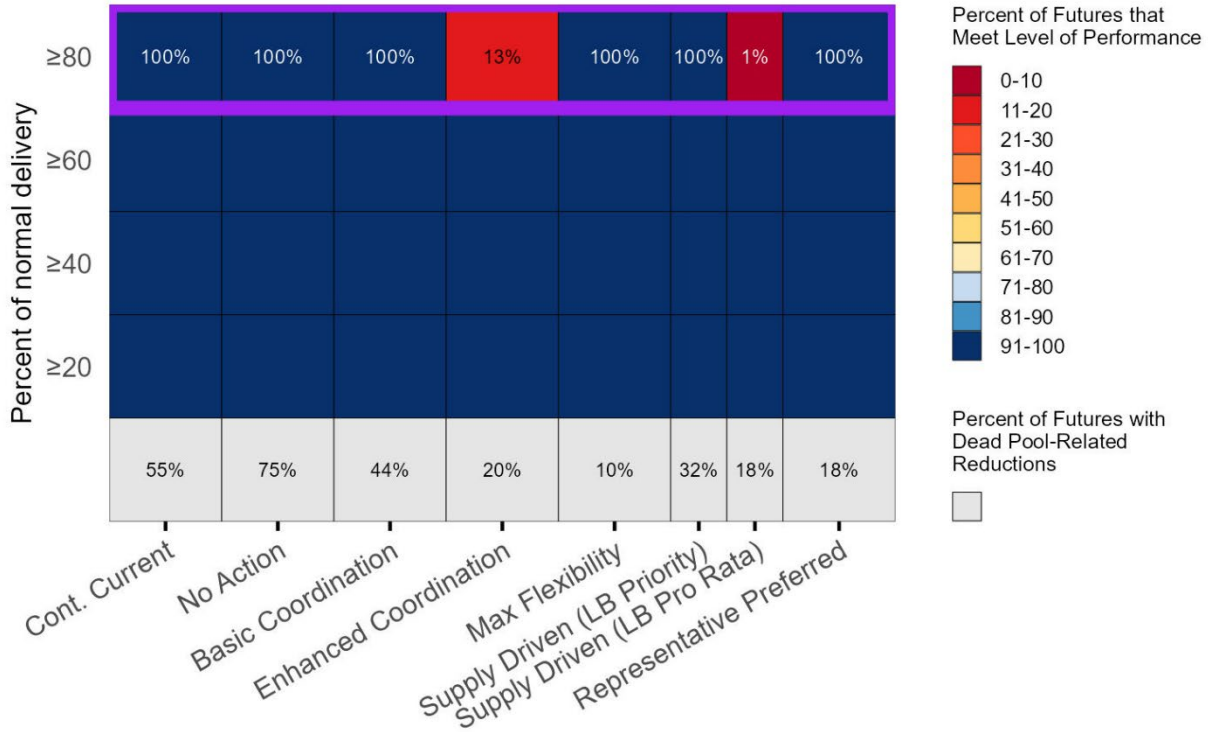
[15] In this context, "preferred minimum performance" and "undesirable performance" are terms selected to understand a modeling analysis, and they do not imply any policy, legal, or other conclusions about the analysis or ITAs.
[16] See **TA 4**, Water Deliveries for more information.
[17] In general, more frequent dead pool–related reductions are associated with lower maximum shortages, and vice-versa.

- A key assumption affecting tribal water deliveries is the shortage distribution method that would be used under Lower Basin shortage conditions. To capture the May 1, 2026 proposal by the Lower Division States for distributing up to 1.5 maf of shortage, the best available information at time of publication, the Representative Preferred Alternative uses the LB Priority distribution method to distribute the first 1.5 maf or shortage for 2027-2028. While the Representative Preferred Alternative models shortages above 1.5 maf in 2028, consistent with the sideboards, under the Preferred Alternative, Reclamation would consult with stakeholders if Lake Mead elevation is projected below 1,000 feet. (See **Chapter 2** for more details on the sideboards under the Preferred Alternative). For 2029-2060, the Representative Preferred Alternative uses the Priority distribution method.

- The DMDU figures do not capture individual years within the modeling period, however, they are modeled. The modeling assumptions for the Representative Preferred Alternative in the first two years (2027–2028) are described in **Chapter 2** and the shortages up to 1.5 maf are distributed via LB priority. Refer to **Appendix C**, **Table C-28** for domestic shortage impacts for each entitlement holder under the LB Priority distribution (up to 1.5 maf shortage). **TA 4**, Water Deliveries, shows analysis of the Representative Preferred Alternative for 2027 and 2028 at the state distribution level. The potential 2027 and 2028 operating guidelines modeling is compared to the Representative Preferred Alternative in **Appendix T**, Preliminary Description and Analysis of Anticipated Operating Guidelines for 2027 and 2028. The results for the Representative Preferred Alternative in 2029–2036, in which the Priority distribution is applied, would result in more shortage impacts on Arizona junior entitlements. Impacts beyond 2028 under the Preferred Alternative may be different from what is shown in the DMDU figures for the Representative Preferred Alternative, as this alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**.

Figure TA 18-3 contains the DMDU full analysis period modeling results for the PPR group. The PPR group contains the most senior water entitlements in the Lower Basin. As shown in the purple-bordered row (the top row), in the CCS Comparative Baseline and all alternatives other than the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, 100 percent of futures meet the assumed preferred minimum performance criteria, meaning that at least 80 percent of the normal water delivery is delivered in 90 percent of the years of a modeled future. This occurs because these are the most senior water entitlements in the Lower Basin, and all alternatives that have 100 percent in the purple-bordered row use a variation of the priority system. Because at least 80 percent of water is delivered in 100 percent of futures for these alternatives, the rows below the purple-bordered row for those alternatives (which indicate lower quantities of delivered water) are also 100 percent and thus are classified into the 91-100 percent category.

Figure TA 18-3
Present Perfected Rights: Robustness (Full Period).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years



For the Enhanced Coordination Alternative, the preferred minimum performance criteria (at least 80 percent of normal water delivery in 90 percent of the years of a future) is met in 13 percent of modeled futures. For the Supply Driven Alternative (LB Pro Rata approach), 1 percent of futures meet the preferred minimum performance criteria. The lower result for these two alternatives is likely due, in part, to these alternatives using a variation of the pro rata distribution, which fulfills these senior water entitlements as though they were equal in priority to other Lower Basin entitlements. While 80 percent of normal water deliveries in 90 percent of years of a future occur in 13 percent of modeled futures under the Enhanced Coordination Alternative, at least 60 percent of water deliveries in all years of a future occur in 91-100 percent of modeled futures. Similarly, at least 60 percent of normal water deliveries would occur in 91-100 percent of modeled futures for the Supply Driven Alternative (LB Pro Rata approach).

Importantly, the analysis does not conclude that all alternatives that meet the preferred minimum performance criteria (the purple-bordered row) in 100 percent of modeled futures perform equally in terms of water deliveries to the PPR priority group. This is because the alternatives have different frequencies of modeled futures in which there is a dead pool–related release, as shown in the gray row at the bottom of the table. Less frequent dead pool–related reductions are better in terms of water deliveries because it means that there are more consistent water deliveries, all else equal. Therefore, among options that meet the preferred minimum performance criteria in 100 percent of

futures, the Maximum Operational Flexibility Alternative would be the most robust (as it minimizes dead pool–related releases) and the No Action Alternative would be the least robust (as it maximizes dead pool–related releases). The Representative Preferred Alternative is the second best performing alternative for this priority group, behind the Maximum Operational Flexibility Alternative. Because the Representative Preferred Alternative assumes a version of the priority distribution method, it performs relatively well for this priority group, which has some of the most senior tribal water entitlements.

The DMDU modeling results for the PPR priority group by subperiod (**Figure TA 18-4**) indicate generally similar relative performance of the CCS Comparative Baseline and the alternatives as those for the full period. As with the full period, in all but the Enhanced Coordination and the Supply Driven (LB Pro Rata approach) Alternatives, at least 80 percent of normal water deliveries in 90 percent of years is estimated to occur in 100 percent of modeled futures. The breakdown by subperiod provides some additional insight into the Enhanced Coordination Alternative. In the 2027-2039 subperiod, 0 percent of futures meet the preferred minimum performance criteria. However, 52 percent and 46 percent of futures meet the preferred minimum performance criteria in the 2040-2049 and 2050-2060 subperiods, respectively. A similar pattern occurs for the Supply Driven Alternative (LB Pro Rata approach), with 0 percent, 28 percent, and 26 percent of futures meeting the preferred minimum performance criteria in the three subperiods, respectively. The lower result for the first subperiod for these two alternatives occurs because the modeled futures start at low reservoir conditions, making it more difficult to deliver full water deliveries under variations of the pro rata distribution method during the 2027-2039 subperiod.

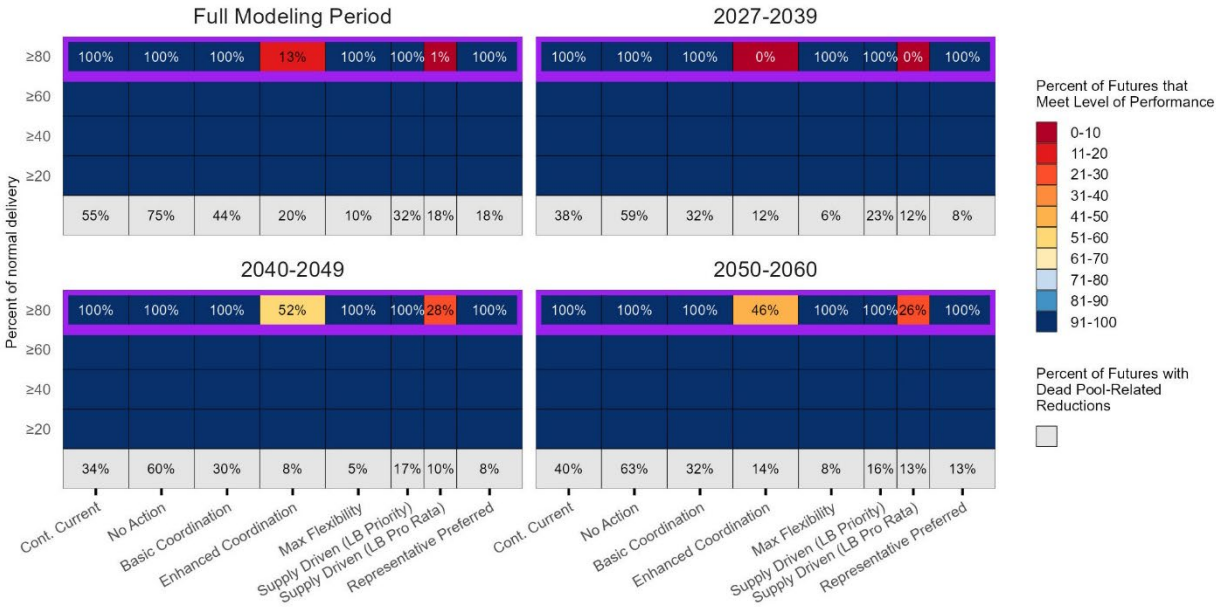
It is important to focus on the first decadal period (2027-2039), as this contains the implementation period of the Preferred Alternative. During this period, the Maximum Operational Flexibility Alternative performs the best, as it meets the preferred minimum performance criteria in 100 percent of modeled futures and has the lowest percent of futures with a dead pool–related release (6 percent). The Representative Preferred Alternative performs nearly as well for this priority group, meeting the preferred performance criteria in 100 percent of modeled futures and having the second-lowest percent of futures with a dead pool-related reduction (8 percent).

The Preferred Alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**, which could yield different impacts than the distribution methods assumed for the Representative Preferred Alternative. The DMDU figures do not capture individual years within the modeling period, however, they are modeled. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results in the full modeling period and the first modeling period are heavily influenced by the Priority distribution method, which is modeled 2029-2060. Entity-specific shortage impacts under each shortage distribution method that was modeled for this EIS are presented in **Appendix C,** Shortage Allocation Model and Alternative Distribution Model Documentation.

Several alternatives meet the preferred minimum performance criteria less frequently in the first subperiod (2027-2039) compared to the later two subperiods (2040-2049 and 2050-2060). This

occurs because the first subperiod follows low flow conditions, reducing operational flexibility and making Lower Basin shortages more common during that time frame.

Figure TA 18-4
Present Perfected Rights: Robustness (by Subperiod).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years



The full period DMDU results for the Arizona Priority 3 group (**Figure TA 18-5**) are the same as for the PPR group except for the Maximum Operational Flexibility Representative Preferred Alternatives. For the Maximum Operational Flexibility Alternative, the preferred minimum performance criteria (at least 80 percent of normal water deliveries in 90 percent of years of a future) is estimated to be met in 64 percent of modeled futures, a decrease in its robustness relative to the PPR group.

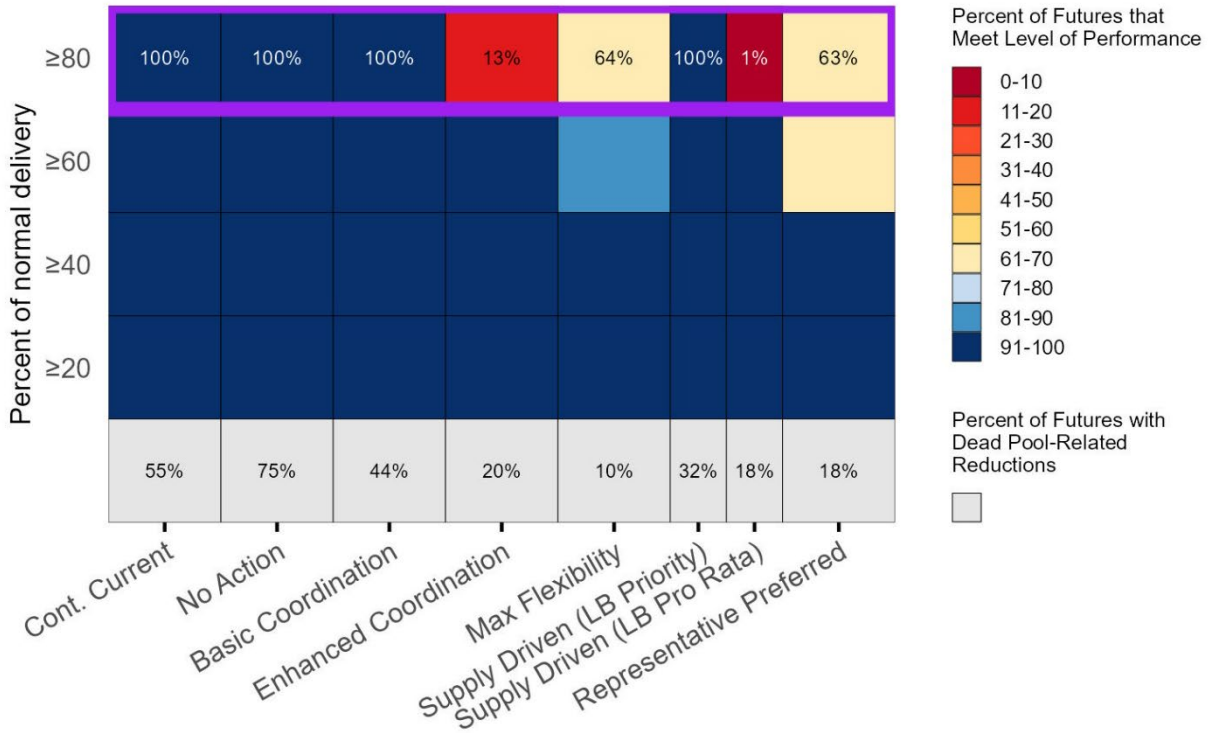
Note that the percentage of futures with a dead pool–related release is independent of the priority group and is therefore the same as in the PPR group results. Similar considerations as described for the PPR group apply.

No alternative is clearly more robust than the others for the Arizona Priority 3 group. Depending on whether one considers the percentage of futures that meet preferred minimum performance criteria or the percentage of futures in which dead pool–related reductions are avoided as more important, the most robust would be either the Supply Driven Alternative (LB Priority Approach; which delivers more water considering only shortages) or the Maximum Operational Flexibility Alternative (which minimizes the frequency of dead pool–related reductions).

The results for the Arizona Priority 3 group by subperiod (**Figure TA 18-6**) do not change the conclusions above concerning the relative robustness of the alternatives; the most robust alternative is either the Supply Driven Alternative (LB Pro Rata) or the Maximum Operational Flexibility

Alternative, depending on whether one prioritizes deliveries considering shortages only or the frequency of dead pool-related reductions.

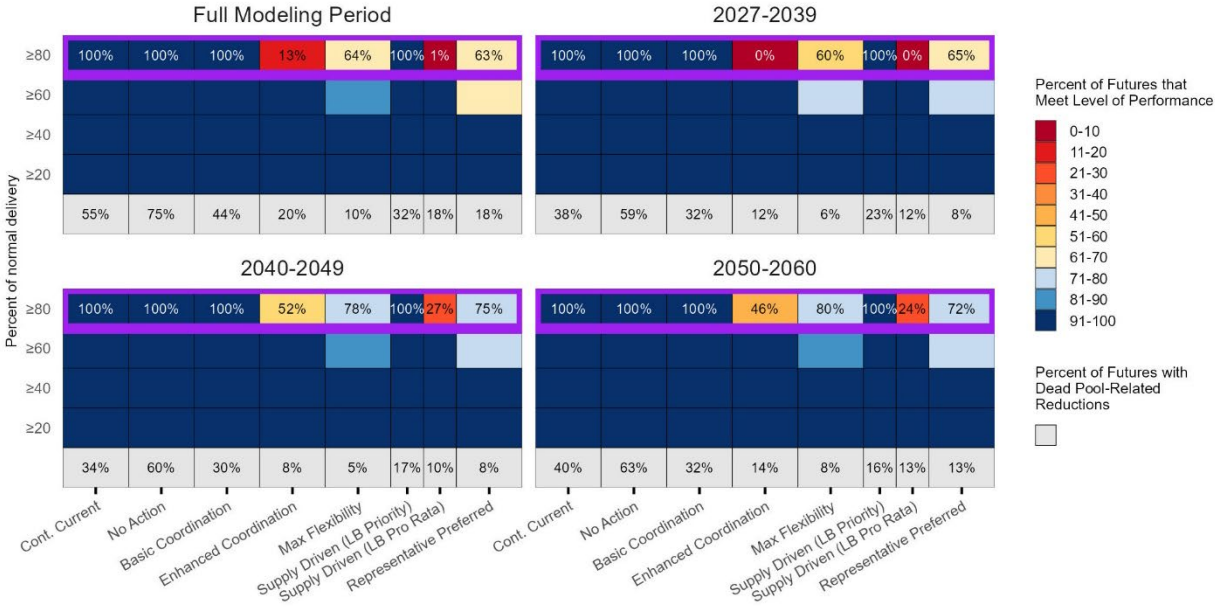
Figure TA 18-5
Arizona Priority 3: Robustness (Full Period).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years



For the first decadal period (2027-2039), which contains the implementation period of the Preferred Alternative, the Representative Preferred Alternative performs second-to-last among the alternatives for deliveries, meeting the preferred performance criteria in 65 percent of modeled futures; however, it has the second-lowest percent of futures with a dead pool-related reduction (8 percent).

The full period DMDU modeling results for the Arizona CAP Indian, CAP M&I, and Arizona Priority 4i group (**Figure TA 18-7**) are very different than the results for the PPR and Arizona Priority 3 groups. Under CCS Comparative Baseline, the preferred minimum performance criteria (at least 80 percent of water is delivered in 90 percent of years of a future) is met in only 13 percent of futures. The No Action Alternative meets the preferred minimum performance criteria in 100 percent of futures. However, as previously noted, this considers only shortages. The No Action Alternative has dead pool–related reductions in 75 percent of futures, implying that full water delivery is unlikely under the No Action Alternative. The Enhanced Coordination Alternative also meets the preferred minimum performance criteria in 13 percent of modeled futures. All other alternatives meet the preferred minimum performance criteria in less than 5 percent of modeled futures.

Figure TA 18-6
Arizona Priority 3: Robustness (by Subperiod).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years

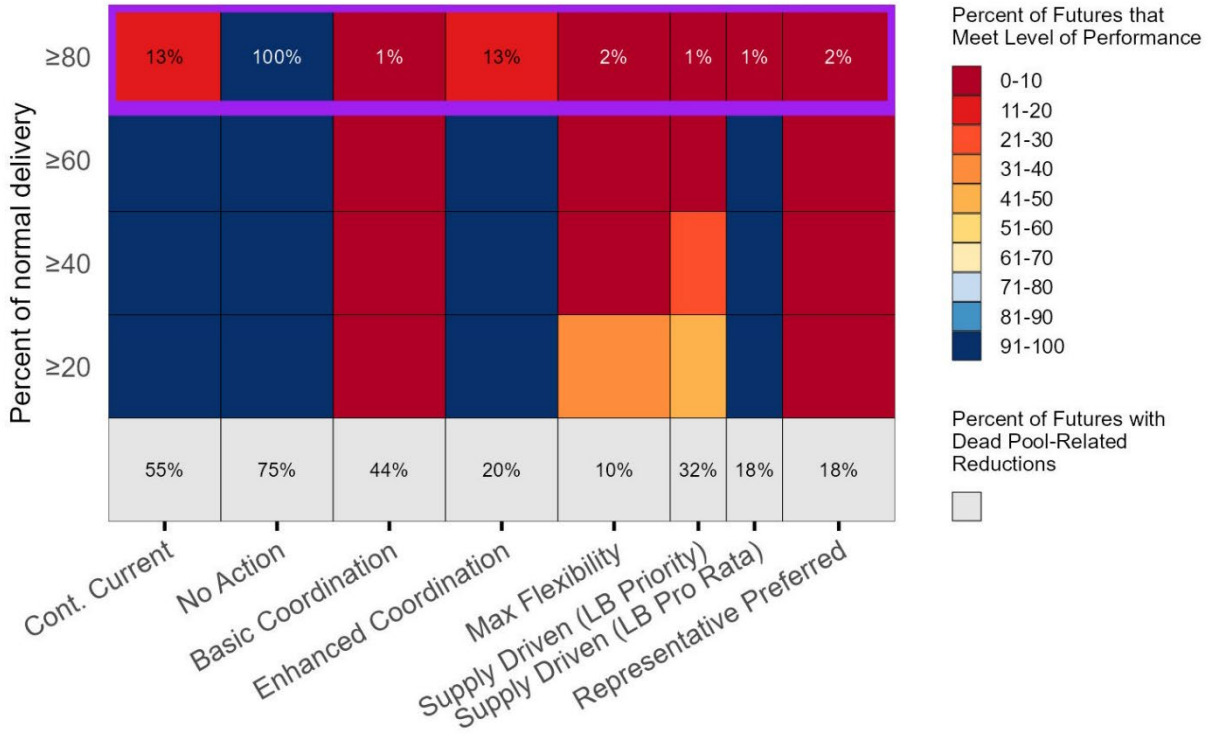


Dropping down to the next highest water delivery threshold (60 percent), the CCS Comparative Baseline and three alternatives (No Action Alternative, Enhanced Coordination Alternative, and Supply Driven Alternative [LB Pro Rata approach]) provide at least 60 percent of normal deliveries in 90 percent of years of a future in 91-100 percent of futures. Of these, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have a lower percentage of futures with dead pool–related releases, which occur in 20 and 18 percent of futures, respectively.

The Representative Preferred Alternative is not robust for this priority group, meeting the preferred performance criteria in only 2 percent of modeled futures over the full modeling period, and 0 percent of modeled futures over the first decadal period (2027-2039), which contains the implementation period of the Preferred Alternative. In addition, the lowest amount of water delivery modeled (at least 20 percent of normal water delivery) occurs in only 1-10 percent of modeled futures. This is because the Representative Preferred Alternative assumes a version of the priority distribution method and this priority group has relatively junior water entitlements. However, the Representative Preferred Alternative still performs second best with respect to dead pool-related reductions.

No alternative is clearly the most robust for this priority group. Depending on whether one considers the percentage of futures that meet preferred minimum performance criteria or the percentage of futures in which dead pool–related releases are avoided as more important, the more robust alternative would be either the No Action Alternative (more water is delivered, considering only shortages) or the Enhanced Coordination Alternative (which meets the preferred performance criteria substantially less often but has a substantially lower frequency of dead pool–related reductions).

Figure TA 18-7
Arizona CAP Indian, CAP M&I, and Priority 4i: Robustness (Full Period).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years



Considering the DMDU modeling for the AZ CAP Indian, CAP M&I, and AZ 4i group results by subperiod (**Figure TA 18-8**), the same high-level performance rankings as the full period hold; the best performing alternatives are the No Action and the Enhanced Coordination Alternatives. However, the Enhanced Coordination Alternative appears more robust by subperiod than when considering only the full period, as it is estimated to be more robust in the two later subperiods compared to the first subperiod and the full period. While the Basic Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives would also be more robust in the later two subperiods compared to the first subperiod and full period, the Enhanced Coordination Alternative continues to be more robust than the other action alternatives for this priority group.

Figure TA 18-8
Arizona CAP Indian, CAP M&I, and Priority 4i: Robustness (by Subperiod).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years

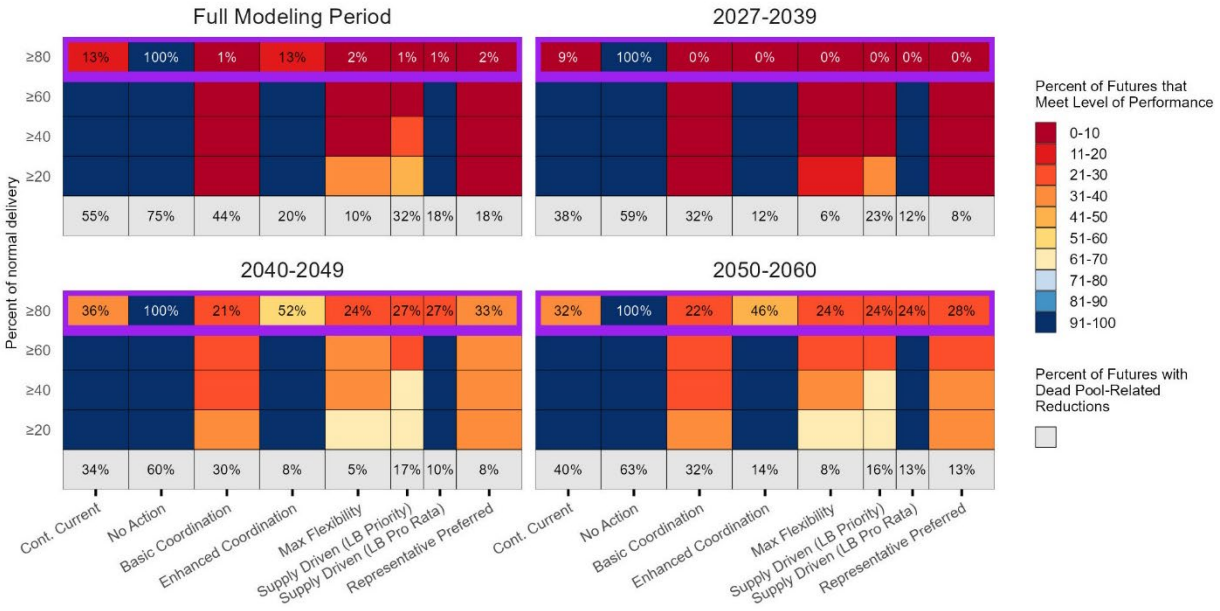


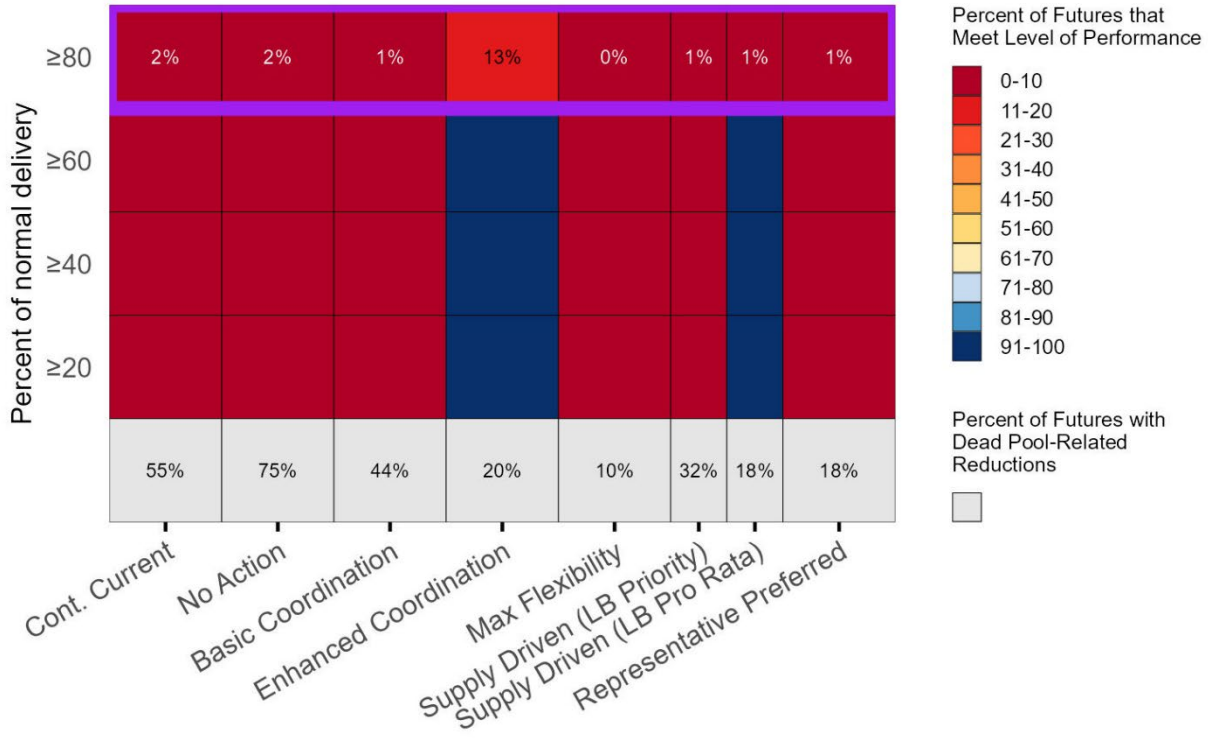
Figure TA 18-9 presents DMDU full period modeling results for the CAP Indian NIA group. These contracts are some of the most junior tribal entitlements in the Lower Basin. As such, it should be expected that deliveries will often be lower during Shortage Conditions compared to other priority groups. With one exception (the Enhanced Coordination Alternative), the CCS Comparative Baseline and the alternatives meet the preferred minimum performance criteria in less than 5 percent of modeled futures. The Enhanced Coordination Alternative meets the preferred minimum performance criteria in 13 percent of modeled futures.

The only two alternatives that consistently deliver water to this priority group are the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives, which deliver at least 60 percent of normal water deliveries in 90 percent of years of a future in 91-100 percent of futures. This is likely due to their use of variations of the pro rata distribution method, which delivers more water to junior entitlements as shortages increase compared to the priority distribution, some variation of which is used by CCS Comparative Baseline and the other alternatives. Combined with its relatively low percentage of futures with a dead pool–related release (16 percent), the Enhanced Coordination Alternative is clearly the most robust alternative for this priority group.

As with the Arizona CAP Indian, CAP M&I, and Arizona Priority 4i group, the Representative Preferred Alternative is not robust for the CAP Indian NIA group, meeting the preferred performance criteria in only 1 percent of modeled futures for the full modeling period and delivering at least 20 percent of normal water deliveries in only 1-10 percent of modeled futures. For the first decadal period (2027-2039), which includes the implementation period for the Preferred Alternative, the Representative Preferred Alternative does not meet the preferred performance criteria in any

modeled futures. This is because the Representative Preferred Alternative assumes a version of the priority distribution method and this priority group has relatively junior water entitlements. However, for dead pool-related reduction, the Representative Preferred Alternative still performs second-best.

Figure TA 18-9
Arizona CAP Non-Indian Agriculture Priority: Robustness (Full Period). Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years



The Preferred Alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**, which could yield different impacts than the distribution methods assumed for the Representative Preferred Alternative. The DMDU figures do not capture individual years within the modeling period, however, they are modeled. While the Representative Preferred Alternative does model shortages up to 1.5 maf using the LB Priority approach in 2027 and 2028, the results in the full modeling period and the first modeling period are heavily influenced by the Priority distribution method, which is modeled 2029-2060. Entity-specific shortage impacts under each shortage distribution method that was modeled for this EIS are presented in **Appendix C**.

The subperiod DMDU modeling results for the CAP Non-Indian Agriculture priority group (**Figure TA 18-10**) show similarities to the subperiod results for other priority groups, specifically that several alternatives are more robust in the later two subperiods compared to the first subperiod and the full period. For this priority group, the rank of the alternatives is not affected by the subperiods; the Enhanced Coordination Alternative continues to be the most robust for this priority group.

Figure TA 18-10
Arizona CAP Non-Indian Agriculture Priority: Robustness (by Subperiod).
Percent of futures in which annual delivery is the percent of normal delivery specified in each row in 90 percent of years

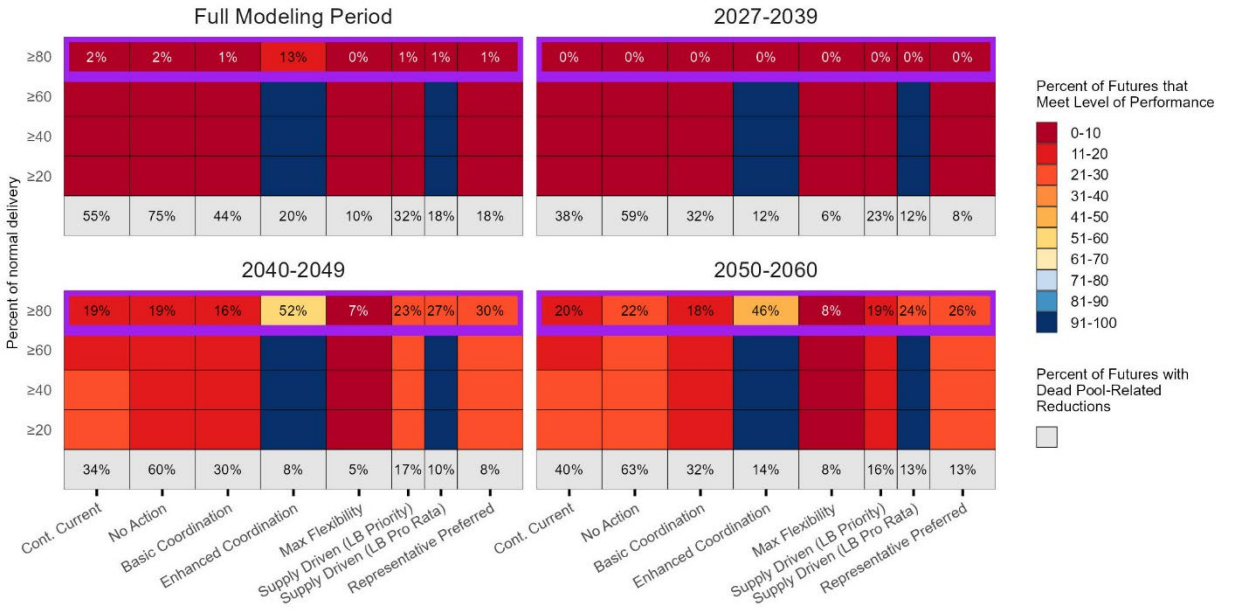
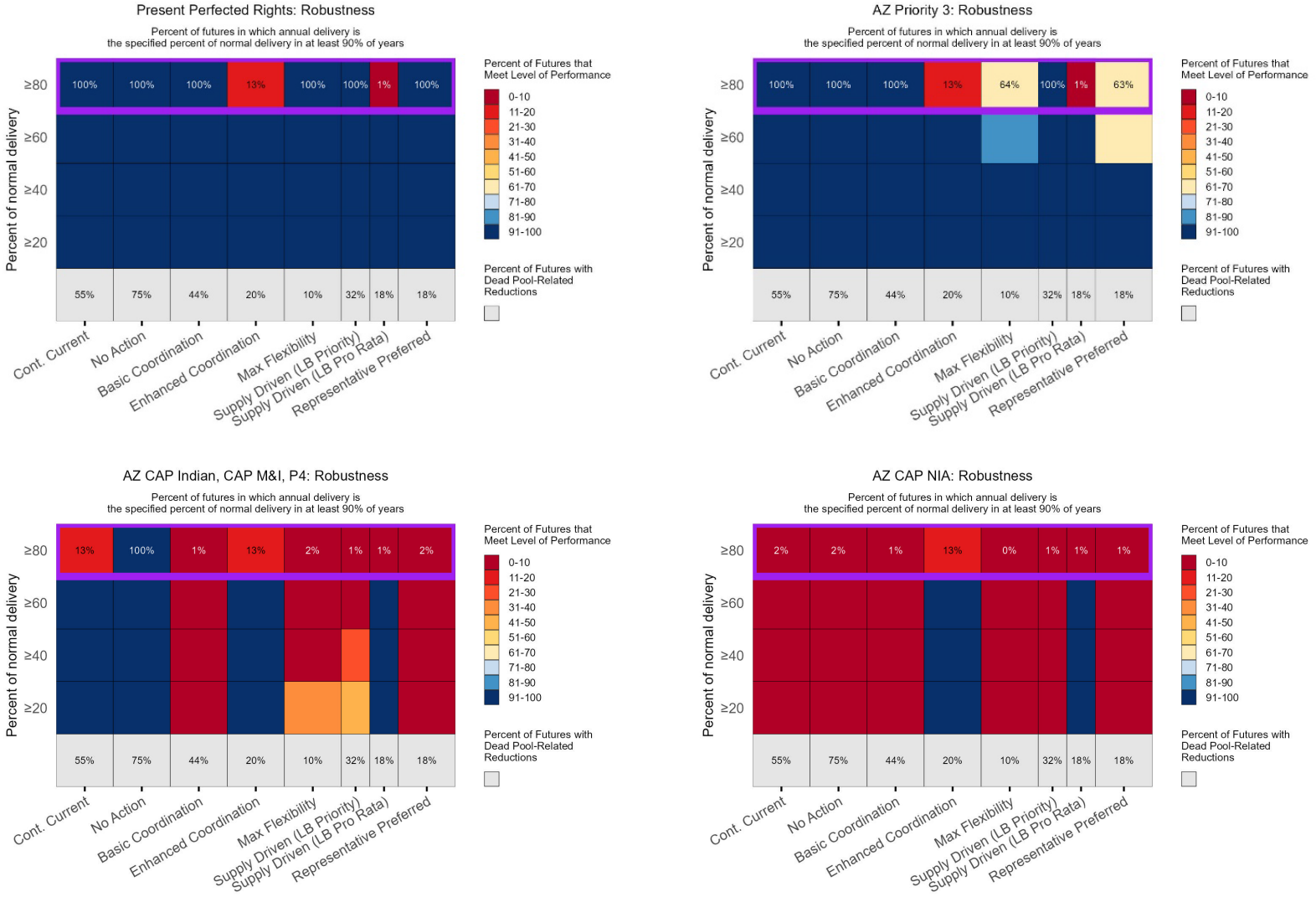


Figure TA 18-11 shows the full-period DMDU modeling results for all priority groups. Key findings differentiating the alternatives in terms of tribal water deliveries across the priority groups based on the full-period DMDU heat maps include the following:[18, 19]

- There is no alternative that is the most robust across the priority groups in terms of maximizing water deliveries to all tribes. The alternatives perform differently for the priority groups and, for some priority groups, depend on the importance placed on results considering only shortages relative to the frequency of futures with dead pool-related releases.

[18] Other key metrics are evaluated and discussed elsewhere in the EIS.
[19] The Preferred Alternative provides a framework that allows for shortages to be distributed based on agreements among states that may arise, consistent with sideboards described in **Chapter 2**, which could yield different impacts than the distribution methods assumed for the Representative Preferred Alternative.

Figure TA 18-11
Robustness Comparison for All Priority Groups (Full Period)



- For the most senior water entitlements (the PPR group), the Maximum Operational Flexibility Alternative is the most robust. It meets the preferred minimum performance criteria in 100 percent of modeled futures and has the lowest percentage of futures with dead pool–related reductions. The Representative Preferred Alternative is the second best performing alternative for this priority group.
- For the next most senior water entitlements priority group (the Arizona Priority 3 group), a case could be made for either the Maximum Operational Flexibility or Supply Driven (LB Priority approach) Alternatives. Which is more robust depends on how this group trades off water delivery, considering only shortages (which favors the Supply Driven Alternative [LB Priority approach]) or minimizing the percentage of futures with a dead pool–related release (which favors the Maximum Operational Flexibility Alternative). The Representative Preferred Alternative is not one of the two top performing alternatives for this priority group.
- For the next most senior water entitlements priority group (the AZ CAP Indian, M&I, AZ 4i group), a case could be made for either the No Action or Enhanced Coordination Alternatives. Which is more robust depends on how this group trades off water delivery, considering only shortages (which favors the No Action Alternative) or minimizing the percentage of futures with a dead pool–related release (which favors the Enhanced Coordination Alternative). The Representative Preferred Alternative is not robust for this priority group.
- For the most junior water entitlements priority group (the AZ CAP NIA group), the Enhanced Coordination Alternative is the most robust. The Representative Preferred Alternative is not robust for this priority group.
- Considering shortages only (that is, not considering dead pool–related reductions), the No Action Alternative is estimated to meet the preferred minimum performance criteria in 100 percent of normal water deliveries to all priority groups except the AZ CAP NIA group. This result is likely due to a lower maximum shortage than other alternatives (**Figure TA 18-1** and **Table TA 18-4**). However, the No Action Alternative has the highest potential for dead pool–related releases of any alternative, with 75 percent of futures estimated to have a dead pool–related release. Therefore, water delivery would be unlikely under the No Action Alternative.
- The CCS Comparative Baseline is similar to the No Action Alternative, except 13 percent of futures meet preferred minimum performance criteria for the CAP Indian, CAP M&I, and AZ 4i priority group, and 2 percent of futures meet the preferred minimum performance criteria for the CAP NIA group. Dead pool–related reductions are estimated to occur in 55 percent of modeled futures, which is less frequent than the No Action Alternative.
- The Representative Preferred Alternative is the second best performer for the PPR priority group. It is not among the most robust alternatives for any other priority group.
- The Basic Coordination Alternative is not among the most robust alternatives for any priority group.
- The Enhanced Coordination Alternative has a more complicated pattern of robustness.
    - 13 percent of futures meet the preferred minimum performance criteria for all priority groups, fewer than some other alternatives. This is likely due to the fact that shortages

start relatively early compared to other alternatives, and there is a high maximum shortage (see **Figure TA 18-1** and **Table TA 18-4**).
    - However, it performs very well in terms of delivering at least 60 percent of normal water, as it does so in 91-100 percent of modeled futures for all priority groups. This result is likely due, in part, to its use of the pro rata distribution method.
    - Finally, it has 20 percent of futures with dead pool–related releases, among the fewest of the options modeled.
- Considering only shortages, the Maximum Operational Flexibility Alternative is more robust than the Enhanced Coordination Alternative for the two more senior water entitlements groups (PPR, Arizona Priority 3) and less robust than the Enhanced Coordination Alternative for the two less senior water entitlements groups (AZ CAP Indian, M&I, and 4i; CAP NIA). It has the lowest percentage of futures with a dead pool–related release (10 percent) of all the options modeled.
- The Supply Driven Alternative (LB Priority approach) generally is more robust than the Maximum Operational Flexibility Alternative with respect to shortages, but has a higher percentage of futures with a dead pool–related release (32 percent).
- The Supply Driven Alternative (LB Pro Rata approach) is closest to the Enhanced Coordination Alternative but does not meet the preferred minimum performance criteria as often and therefore is less robust.

It is important to consider the first subperiod, as the Preferred Alternative is a 10-year decision framework. The conclusions above all hold for the first decadal subperiod with the one exception: for the Arizona Priority 3 group, a case could be made that either the Maximum Operational Flexibility, Supply Driven (LB Priority approach), or Representative Preferred Alternatives are the best performing.[20] These three alternatives have various trade-offs between water deliveries considering only shortages and the percentage of futures with a dead pool-related reduction.

Storage and Conservation Options

The No Action and Basic Coordination Alternatives have no water storage mechanisms that would affect Lower Basin Tribes or the quantities of water available to them. Under both alternatives, water conserved under previous mechanisms that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. The other four alternatives do contain new water storage and conservation mechanisms, which are summarized below. See **Chapter 2** and **Appendix S** for a full description of these mechanisms and how they would operate. Note that in all cases, stored water would be available for water transactions with other Lower Basin water users, both within and across Lower Division States.

- Under the Preferred Alterative, Lower Basin water users would be able to store up to 7.0 maf in conservation pool in Lake Mead, including the storage of pre-2027 intentionally created surplus (ICS). There would also be a Federally Managed Water Resources Pool. This

[20] In the full period results, the Maximum Operational Flexibility Alternative performs better than the Representative Preferred Alternative.

pool could potentially be filled by, among other mechanisms, compensated Lower Basin tribal water (conserved consumptive use).

- Under the Enhanced Coordination Alternative, water conserved by Lower Basin water users could be stored in a Lake Mead conservation pool. There would also be a Reclamation-controlled Federal Lake Mead conservation pool. Water for the Federally Managed Water Resources Pool could be voluntarily acquired by compensation for conserved water, among other mechanisms. Previously stored ICS water would be transferred into the non-Federal Lake Mead conservation pool and would be subject to the new provisions regarding the release of that water.
- Under the Maximum Operational Flexibility Alternative, water conserved by Lower Basin water users could be stored in a combined pool managed across both Lake Powell and Lake Mead. Previously stored ICS water would be transferred into this pool, and the new provisions regarding the release of that water would apply.
- Under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), Lower Basin water users could contribute to a storage pool in Lake Mead. Previously stored ICS water would be converted into this conservation pool over 10 years, and then the new provisions regarding the release of that water would apply.

All else equal, the four alternatives that include new mechanisms for storage and conservation of water could provide additional options to Lower Basin Tribes. First, the mechanisms allow tribes to conserve water and participate in storage programs. Second, the mechanisms allow transactions with other Lower Basin water users. Third, tribes that participate could receive compensation for conserved consumptive use. However, whether these new mechanisms are better for any specific tribe compared to the current ICS mechanism is outside the scope of this analysis.

TA 18.2.3 Issue 2: How Will Changes in Dam Operations Affect Indian Trust Lands?

Changes in dam operations under the different alternatives would not affect the borders of established reservations or the definitions of any trust lands. Trust land will remain trust land. Future potential acquisitions of land into trust are not limited by the operations. Further, in addition to (uncontrollable) drought conditions in any given year, the different alternatives of various distributions of the available water could add an incremental impact to the use of trust lands. An important aspect of the use of trust lands involves agricultural land, as fluctuations in water levels are estimated to result in some tribal agricultural lands being fallowed. Other changes in the use of tribal land and resources are discussed in **TA 13**, Tribal Resources. The considerations therein generally apply to Trust and non-Trust resources.

Agricultural Land

The potential impacts of changes in dam operations on agricultural land are assumed to be inversely dependent on water deliveries, meaning agricultural impacts are estimated to increase as water deliveries decrease.

Upper Basin

As noted in the Upper Basin water deliveries section above, none of the alternatives would affect water deliveries to Upper Basin Tribes. However, changes in storage and conservation options under some

alternatives could provide opportunities for tribal participation. All else equal, the new mechanisms for conserving and storing water for Upper Basin Tribes (contained in the Preferred, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven [both LB Priority and LB Pro Rata approaches] Alternatives) would provide additional options for tribes in the Upper Basin.

Lower Basin

TA 16, Socioeconomics, discusses the potential impacts of changes in dam operations and resulting changes in water deliveries on tribal and non-tribal agricultural economies in the Lower Basin. Estimates are presented for several socioeconomic metrics: acres of fallowed agricultural land, direct market value, jobs, and economic output. Results are presented at the state level and by priority groups for Arizona, California, and Nevada. See **TA 16**, Socioeconomics, for a full discussion of the modeling and results. This section focuses on the acres of fallowed land as an indicator of potential impacts on Trust land.

Table TA 18-5 summarizes the modeling results for estimated changes in fallowed tribal agricultural land. For each state and alternative and the CCS Comparative Baseline, the table shows the estimated acres fallowed under two scenarios: a shortage of 0.6 maf, which is applicable to all alternatives and the CCS Comparative Baseline; and the acres of fallowed land under the maximum shortage, which varies across each alternative and the CCS Comparative Baseline. As discussed for Lower Basin water deliveries above, the results must also be understood in the context of the possibility for dead pool–related reductions. See the Water Deliveries section of this Final EIS for more information on dead pool–related releases. **Table TA 18-5** contains the percentage of dead pool–related releases for each alternative and the CCS Comparative Baseline.

Some key findings from **Table TA 18-5** include:

- Similarly to the Lower Basin water deliveries analysis above, the seniority of water entitlements combined with the distribution method makes a large difference in the results.
- Tribal agriculture in Arizona is estimated to experience the largest impacts in terms of the absolute changes in acres of fallowed land. This is likely because the majority of the reservation land is in Arizona (see **Map TA 18-1**). The Representative Preferred Alternative is modeled to fallow the second-least number of acres in Arizona, relative to the other alternatives.
- No alternative is clearly the most robust for Arizona. The different alternatives and the CCS Comparative Baseline have varying trade-offs between fallowed acreage under shortages and percent of futures with dead pool-related reductions.
- In California and Nevada, impacts are only associated with alternatives that use the pro rata distribution method (the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives).
- All other alternatives, including the Representative Preferred Alternative, and the CCS Comparative Baseline use some variation of the priority distribution method and estimate no reductions in water deliveries, and therefore no fallowed agricultural land, in these states.
- The Maximum Operational Flexibility Alternative performs the best for California and Nevada, as there are zero fallowed acres and the percentage of futures with dead pool–related reductions is minimized. This would be true for PPRs in Arizona as well.

Table TA 18-5
Estimated Tribal Agricultural Land Fallowed under Lower Basin Water Shortages

State	Alternative (or CCS Comparative Baseline)	Acres Fallowed at Shortage of 0.6 maf	Acres Fallowed at Maximum Shortage	Percent of Futures with Dead pool–related Reductions
Arizona	CCS Comparative Baseline	15,586	22,254	55
Arizona	No Action	12,419	12,419	75
Arizona	Basic Coordination	12,419	49,582	44
Arizona	Enhanced Coordination	8,067	39,200	20
Arizona	Maximum Operational Flexibility	6,535	68,054	10
Arizona	Supply Driven (LB Priority approach)	6,535	53,560	32
Arizona	Supply Driven (LB Pro Rata approach)	15,794	38,605	18
Arizona	Representative Preferred Alternative	6,535	67,375	18
California	CCS Comparative Baseline	0	0	55
California	No Action	0	0	75
California	Basic Coordination	0	0	44
California	Enhanced Coordination	1,298	5,092	20
California	Maximum Operational Flexibility	0	0	10
California	Supply Driven (LB Priority approach)	0	0	32
California	Supply Driven (LB Pro Rata approach)	579	2,803	18
California	Representative Preferred Alternative	0	0	18
Nevada	CCS Comparative Baseline	0	0	55
Nevada	No Action	0	0	75
Nevada	Basic Coordination	0	0	44
Nevada	Enhanced Coordination	131	656	20
Nevada	Maximum Operational Flexibility	0	0	10
Nevada	Supply Driven (LB Priority approach)	0	0	32

State	Alternative (or CCS Comparative Baseline)	Acres Fallowed at Shortage of 0.6 maf	Acres Fallowed at Maximum Shortage	Percent of Futures with Dead pool–related Reductions
Nevada	Supply Driven (LB Pro Rata approach)	131	460	18
Nevada	Representative Preferred Alternative	0	0	18

Source: **TA 16** Socioeconomics, **Figure TA 16-1**

TA 18.2.4 Issue 3: How Will Changes in Dam Operations Affect Other Indian Trust Assets?

Changes in dam operations would not directly affect the status and corpus of other ITAs. Trust assets will remain trust assets. Future potential acquisitions of assets into trust are not limited by the operations. Further, in addition to (uncontrollable) drought conditions in any given year, changes in dam operations could incrementally affect water levels, vegetation, fish, and wildlife, and therefore could indirectly affect the use of ITAs. General changes in vegetation, fish, and wildlife are discussed in their respective sections of this Final EIS.

As noted in **Section TA 18.1.3**, income is not a trust asset, yet Reclamation recognizes that income derived from ITAs can be important to tribes. Impacts on specific income-generating activities depend on a complex array of legal, contractual, and environmental factors. Because income derived from ITAs varies for each tribe, the effects of changes in water levels and deliveries due to the alternatives will also vary by tribe.

However, several general conclusions can be drawn regarding tribes' ability to generate income from leasing water. All else equal, higher quantities of delivered water means more ability to fulfill existing lease agreements and/or enter into new agreements. From this perspective, the conclusions of the water deliveries analysis generally apply to water leases.

Fees for outdoor recreation and other services on tribal land that generate income could be affected by changes in dam operations that result in changes in access, changes in river flows, changes in water quality, changes in fish and wildlife, and other resources that affect outdoor recreation. **TA 14**, Recreation, discusses the expected impacts of the alternatives on recreation.

TA 18.2.5 Summary Comparison of Alternatives

Issue 1: Tribal Water Entitlements, Deliveries, and Storage and Conservation Options

Water Entitlements

The alternatives would not affect entitlements to any Upper Basin or Lower Basin Tribes. The approaches to distributing Lower Basin shortages incorporated in all alternatives are designed to explore a wide range of potential concepts and impacts; they do not reflect an intention by Reclamation to alter apportionments or water entitlements. However, because the concepts would affect a range of users, impacts on deliveries to different entities are analyzed, and addressed in **Appendix C**, Shortage Allocation Model and Alternative Distribution Model Documentation.

Water Deliveries

The alternatives would not affect deliveries to any Upper Basin water users, including tribes.

For water deliveries in the Lower Basin, the most robust alternative in terms of estimated water deliveries depends on the priority group.

- For the most senior water entitlements (the PPR group), the Maximum Operational Flexibility Alternative clearly is the most robust. It meets the preferred minimum performance criteria in 100 percent of modeled futures and has the lowest percentage of

futures with dead pool–related reductions. During the first modeling period, which includes the implementation period for the Preferred Alternative, the Representative Preferred Alternative performs second-best to the Maximum Operational Flexibility Alternative, with nearly the same performance.

- For the next most senior water entitlements priority group (the Arizona Priority 3 group), a case could be made for either the Maximum Operational Flexibility or Supply Driven (LB Priority approach) Alternatives. Which is more robust depends on how this group trades off water delivery, considering only shortages (which favors the Supply Driven [LB Priority approach] Alternative) or minimizing the percentage of futures with a dead pool–related release (which favors the Maximum Operational Flexibility Alternative). For the first decadal period, which contains the implementation period of the Preferred Alternative, the Representative Preferred Alternative performs second-to-last among the alternatives for deliveries, meeting the preferred performance criteria in 65 percent of modeled futures; however, it has the second-lowest percent of futures with a dead pool-related reduction.
- For the next most senior water entitlements priority group (the AZ CAP Indian, M&I, AZ 4i group), a case could be made for either the No Action or Enhanced Coordination Alternatives. Which is more robust depends on how this group trades off water delivery, considering only shortages (which favors the No Action Alternative) or minimizing the percentage of futures with a dead pool–related release (which favors the Enhanced Coordination Alternative). For the first decadal period, which contains the implementation period of the Preferred Alternative, the Representative Preferred Alternative is not robust for deliveries, meeting the preferred performance criteria in 0 percent of modeled futures; however, it has the second-lowest percent of futures with a dead pool-related reduction.
- For the most junior water entitlements priority group (the AZ CAP NIA group), the Enhanced Coordination Alternative is the most robust. For the first decadal period, which contains the implementation period of the Preferred Alternative, the Representative Preferred Alternative is not robust for deliveries, meeting the preferred performance criteria in 0 percent of modeled futures; however, it has the second-lowest percent of futures with a dead pool-related reduction.

Storage and Conservation Options

For Upper Basin Tribes, options for conserving and storing water vary among the alternatives. For the No Action and Basic Coordination Alternatives, there would be no new mechanisms to conserve and store water. However, the Preferred, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have new mechanisms for Upper Basin Tribes to conserve and store water in either or both Lake Powell and Lake Mead.

For Lower Basin Tribes, options for conserving and storing water vary among the alternatives. For the No Action and Basic Coordination Alternatives, there would be no new mechanisms to conserve and store water. Water conserved under previous mechanisms that remains in Lake Mead in 2027 would be delivered in accordance with existing agreements. However, the Preferred, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives all have new mechanisms for Lower Basin Tribes to

conserve and store water in either or both Lake Powell or Lake Mead. These four alternatives also have provisions for converting previously stored ICS water into the new conservation pools. The Enhanced Coordination and Preferred Alternatives are unique in that they would have both user-controlled and Reclamation-controlled conservation pools in Lake Mead, the latter of which could be filled in part by compensating tribes for voluntarily conserving water.

Issue 2: Indian Trust Lands

None of the alternatives would affect the boundaries of established reservations or Trust lands. However, the alternatives would affect the use of Trust lands. Changes in water deliveries could particularly affect the productivity of agricultural land, an important and valuable land use for tribes (Curtis et al. 2023). It is estimated that agricultural land would be fallowed under some alternatives.

In the Upper Basin, none of the alternatives would directly affect agricultural land. Some alternatives would provide new mechanisms for conserving and storing water for Upper Basin Tribes (the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven [both LB Priority and LB Pro Rata approaches] Alternatives).

The following summarizes state-level conclusions in the Lower Basin:

- There is no clear most robust alternative for Arizona. The different alternatives and the CCS Comparative Baseline have varying trade-offs between fallowed acreage under shortages and percent of futures with dead pool-related reductions. The Representative Preferred Alternative is modeled to fallow the second-least number of acres in Arizona, relative to the other alternatives.
- In California and Nevada, impacts are only associated with alternatives that use a pro rata distribution (the Enhanced Coordination and Supply Driven [LB Pro Rata approach] Alternatives). There are no impacts associated with alternatives, including the Representative Preferred Alternative, that use a variation of a priority distribution.

Issue 3: Other Indian Trust Assets

The alternatives would not generally affect other ITAs, but could affect the use of other ITAs. Because impacts are resource- and tribe-specific, no general comparison of alternatives for other ITAs can be made.

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Technical Appendix 19

Visual Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
2024 Final SEIS	Near-term Colorado River Operations Final Supplemental Environmental Impact Statement
CCS	Continued Current Strategies
DMDU	Decision Making under Deep Uncertainty
EIS	environmental impact statement
GCNP	Grand Canyon National Park
HFE	high-flow experiment
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
NRA	National Recreation Area
U.S.	United States

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TA 19. Visual Resources

TA 19.1 Affected Environment

Visual resources are the physical features that make up the visible landscape, including land, water, vegetation, topography, and human-made features such as buildings, roads, utilities, and structures. They also include the response of viewers to those features.

Visual resources are important both to visitors to Grand Canyon National Park (GCNP), Glen Canyon National Recreation Area (NRA), and Lake Mead NRA, and to the Basin Tribes who use these lands for subsistence or ceremonial uses. The Grand Canyon Protection Act of 1992 specifically calls for the conservation of visual resources, which are also a key component of federal management of these areas. GCNP, Glen Canyon NRA, and Lake Mead NRA are managed under their general management plans, which identify management directions for visual resources as part of the plans. These plans are described below.

The portion of the Colorado River adjacent to Lake Powell, as well as a portion of the river upstream and downstream of Lake Powell, is managed under the Glen Canyon NRA General Management Plan. Large areas of Glen Canyon NRA, including those adjacent to the Colorado River, are managed as a natural zone, which includes ". . . the recreation area's outstanding scenic resources, relatively undisturbed areas isolated and remote from the activities of man . . ." (NPS 1979, 5).

Farther downstream, the landscapes adjacent to the Colorado River are managed under the GCNP General Management Plan, which also identified the lands adjacent to the river as a natural zone, which is managed to ". . . conserve natural resources and ecological processes and to provide for their use and enjoyment by the public in ways that do not adversely affect these resources and processes" (NPS 1995, 19).

Past GCNP, the portion of the Colorado River adjacent to Lake Mead and downstream to Bullhead City is managed under the Lake Mead NRA General Management Plan. An amended plan from 2018, to address low-water levels, does not specifically address visual resources; however, it does acknowledge that "Lowering lake levels exposes new shoreline, which is susceptible to the spread of weeds and invasive nonnative plants" and "The appearance of mineral deposits, mudflats, denuded shorelines, and abandoned high-grounded facilities detract from the scenery of the lake" (NPS 2018, 5).

TA 19.1.1 Lake Powell and Glen Canyon Dam

Landscape Character

The landscapes of the Lake Powell and Glen Canyon area are characterized by sweeping vistas of red rock towers, buttes, and mesas typical of the Colorado Plateau (Fenneman 1931). Navajo Sandstone and desert varnish dominate the existing landscape character, with the introduction of water, associated with Lake Powell, framing these natural features.

Lake Powell has deposits of calcium carbonate, which become visible as reservoir levels decrease. At lower lake elevations, the colorful sandstone canyon walls show a light-toned band of calcium carbonate deposit between the full reservoir elevation and the lower reservoir elevation, which contrasts with the natural, red-colored sandstone (see **Figure TA 19-1**). At lower lake elevations, motorists view the calcium carbonate ring from Utah State Route 95 (Utah Bicentennial Scenic Byway; near Hite, Utah), boaters view it on Lake Powell, recreationists see it at developed and undeveloped recreation areas (for example, Hite, Bullfrog, Halls Crossing, Antelope Point, and Wahweap), and hikers see it on trails adjacent to Lake Powell.

Figure TA 19-1
Photo of Existing Calcium Carbonate Rings at Lake Powell



Source: USGS 2022

Additionally, sediment deltas have formed near the inflow areas of Lake Powell from sediments carried by the Colorado River, San Juan, Dirty Devil, and Escalante Rivers, resulting in downstream-progressing deltas. These appear as expansive, deep, and eroding mud flats cut by river channels. Similarly, lower reservoir levels also expose a band of exposed sediment along the shoreline, which in some areas may expose trash and other waste adjacent to Lake Powell. Sediment exposed for more than a few months is soon colonized by tamarisk, an invasive shrub. These sediment deltas and exposed shoreline areas are considered a visual distraction, particularly as the reservoir elevation decreases and these features become more visible. The sediment deltas and exposed shoreline areas can be seen from viewing locations, including Utah State Route 95 and scenic overlooks adjacent to these inflow areas; water-based recreationists can also see the deltas and exposed shoreline from Lake Powell.

Attraction Features

The analysis focuses on the following specific attraction features that were selected to focus on visibility of specific geological features and the dams associated with each reservoir. Note that the discussion of potential impacts on recreation sites and other viewing locations is described under Issue Statement 2 with further information described in **TA 14**, Recreation.

- **Rainbow Bridge:** Contained within Rainbow Bridge National Monument, which was established in 1910, Rainbow Bridge was originally only accessible via the rugged Wetherill Trail from Navajo Mountain. Today, no facilities support visitation to Rainbow Bridge National Monument from Lake Powell. All infrastructure (docks and restrooms) was relocated to the main channel in 2021, due to the narrowing of the canyon and a delta that has formed at the back of the canyon. Some small, motorized vessels may be able to access the monument; however, they must beach their boat, and the walk may be through very soft sediment to reach the trail. Based on lower lake elevations, visitors do not see water under or near the Rainbow Bridge. Therefore, while Rainbow Bridge is an important visual resource, the potential impacts on access would be the primary effect on visitors; these impacts are described in **TA 14**, Recreation.
- **Cathedral in the Desert:** Lake Powell's waters inundated this feature as the reservoir filled. This feature is only exposed at lower Lake Powell elevations, and it is completely visible and accessible when reservoir elevations are below 3,550 feet. However, boats may not be able to reach it at reservoir elevations below 3,525 feet. Note that other attraction (geological) features, including Gregory Bridge, La Gorce Arch, and other features inundated by Lake Powell, could also become visible at lower lake elevations.
- **Glen Canyon Dam:** The American Society of Civil Engineers considers this dam one of the finest examples of concrete, thin-arch dams in the United States (U.S.). The dam is visible from the adjacent visitor center and from a designated overlook location approximately 0.5 miles south of the dam. While visibility of the dam as an attraction feature is part of the current visual landscape in this area, as reservoir levels decrease, exposing more of the dam's concrete structure, its effect on the area's landscape character increase and further dominate the area's natural landscape character.

TA 19.1.2 Glen Canyon Dam to Lake Mead

Landscape Character

The landscape character along the Colorado River within GCNP and Glen Canyon NRA, as well as within the Hualapai and Navajo Indian Reservations, is defined by towering cliff faces with banded rock strata containing a variety of colors, including reds, oranges, grays, browns, and white. The Colorado River Management Plan builds on this for the portion of the Colorado River in Grand Canyon, stating that it provides "a unique combination of thrilling whitewater adventure and magnificent vistas of a remarkable geologic landscape including remote and intimate side canyons" (NPS 2006, 2).

Vegetation along the river mostly consists of riparian species, such as native willows; nonnative and invasive tamarisk (salt cedar); and isolated areas of cottonwoods and cattails, bulrushes, and reeds in return-current channels (backwaters), channel margins, and mouths of tributary streams from Glen Canyon Dam downstream to Lake Mead. These tributary streams form numerous side canyons leading away from the Colorado River, with many of these side canyons only accessible from the river. Vegetation farther upslope along rock terraces includes saltbush, arrowweed, rabbitbrush, and other arid-adapted plant species.

Previously planned and implemented high-flow experiments (HFEs) from Glen Canyon Dam, to re-create natural floods common before Glen Canyon Dam's construction, have allowed for the transportation and deposition of sand, resulting in the formation of sandbars along the river. In some areas, these HFEs can strip vegetation along the existing sandbars, including tamarisk (salt cedar), which allows the landscape to appear more similar to its natural character.

This portion of the Colorado River does not include visible calcium carbonate rings, sediment deltas, or exposed shoreline. This is because this portion is not contained within an area of fluctuating reservoir levels associated with Lake Powell and Lake Mead.

Attraction Features

This portion of the river, including GCNP, is heavily visited and has been determined to be an eligible (but not yet designated) wild river segment by the National Park Service associated with the Wild and Scenic Rivers Act (Barnes 2005). It includes world-renowned whitewater rafting and other recreational opportunities along the Colorado River, including boating, kayaking, swimming, and fishing, in addition to viewing this varied, high-quality landscape from along the river and from scenic overlooks above the river. The river is also viewed from proposed wilderness areas adjacent to the river, including superior views from high points in these areas. See **TA 14**, Recreation, and **TA 17**, Population and Land Use, for more information regarding recreational opportunities and special management areas along the Colorado River.

TA 19.1.3 Lake Mead to Hoover Dam

Landscape Character

The landscapes of the Lake Mead and Hoover Dam area are similar to those described for the Lake Powell area, except the adjacent landscapes are more typical of the Basin and Range physiographic

province, characterized by parallel, north–south-oriented mountain ranges surrounded by nearly level, typically undrained basins (Fenneman 1931).

Similar to Lake Powell, Lake Mead also has deposits of calcium carbonate, which become visible as reservoir levels decrease. At lower lake elevations, the steep rock slopes, canyon walls, and islands show a light-toned band of calcium carbonate deposit between the full reservoir elevation and the lower reservoir elevation, which contrasts with the natural rock colors. At lower lake elevations, motorists view the calcium carbonate ring on U.S. Highway 93 (between Boulder City, Nevada, and Hoover Dam), boaters view it on Lake Mead, and hikers see it on trails adjacent to Lake Mead. Sediment deltas have been built up at the confluence of the Virgin River and Muddy River at the upper Overton Arm and at upper Lake Mead (Iceberg Canyon, Pearce Basin, and lower Granite Gorge).

Similarly, lower reservoir levels also expose a band of exposed sediment along the shoreline, which in some areas may expose trash and other waste adjacent to Lake Mead. Sediment exposed for more than a few months is soon colonized by tamarisk, an invasive shrub. Sediment deltas and the exposed shoreline are visible primarily to water-based recreationists. Visitors to Lake Mead NRA at Overton Beach and Pearce Ferry can also view them.

Attraction Features

The analysis focuses on the following specific attraction feature:

- **Hoover Dam:** Hoover Dam is a major destination and national landmark with high levels of visitation. In 1955, the American Society of Civil Engineers selected it as one of the seven engineering wonders in the U.S. Since Hoover Dam is in the narrow, steep-walled Black Canyon, only a small portion of Lake Mead is visible from Hoover Dam and the adjacent visitor facilities. While visibility of the dam as an attraction feature is part of the current visual landscape in this area, as reservoir levels decrease, exposing more of the dam's concrete structure, its effect on the area's landscape character increase and further dominate the area's natural landscape character.

TA 19.1.4 Hoover Dam to Southerly International Boundary

The landscapes from the Hoover Dam area to the Southerly International Boundary are characterized by arid mountain ranges and intervening desert plains associated with the Basin and Range physiographic province (Fenneman 1931). Availability of Colorado River water has resulted in large areas of irrigated landscapes, including agricultural lands in Arizona, California, and Nevada (Lower Division States), which have altered the natural landscapes. This increased water availability has introduced vivid greens into these landscapes, associated with crops and ornamental plantings, which expand the influence of the Colorado River into adjacent arid lands beyond the narrow, natural riparian corridor.

TA 19.2 Environmental Consequences

TA 19.2.1 Methodology

The Bureau of Reclamation (Reclamation) used similar methods to those used in the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines; Reclamation 2007) and Near-term Colorado River Operations Final Supplemental Environmental Impact Statement (2024 Final SEIS) to analyze potential impacts on visual resources. This analysis assesses the potential effects on attraction features, the extent of the visible calcium carbonate ring, and exposure of sediment deltas at reservoir inflow areas while incorporating the Decision Making under Deep Uncertainty (DMDU) framework for this Final Environmental Impact Statement (EIS). Additionally, this analysis considers the effects of expanded shoreline exposure on the area's landscape character.

The assessment of effects on landscape character adjacent to Lake Powell and Lake Mead used similar methods as identified in the 2007 Final EIS and 2024 Final SEIS. However, using modeling and DMDU concepts, the analysis first focuses on the percentage of time during the planning window that Lake Powell would decrease below elevation 3,550 feet. At that elevation, Cathedral in the Desert (and other attractions [geological] features, including Gregory Bridge, La Gorce Arch, and other features inundated by Lake Powell) would become visible and accessible. Based on historical averages, Lake Powell was below 3,550 feet in approximately 9.9 percent of months between October 2007 and May 2025. The alternatives' comparison focuses on maintaining this lake elevation for at least 10 percent of the months during the planning window. Conversely, this analysis also identifies the percentage of preferred minimum performance of futures in which Lake Powell would be above 3,550 feet, resulting in less of the upstream side of Glen Canyon Dam being visible, because higher reservoir levels obscure the structure.

The potential height of the calcium carbonate ring was calculated by comparing differing reservoir elevations with the full pool elevations of Lake Powell (3,700 feet) and Lake Mead (1,229 feet) under DMDU concepts. The assessment of effects from sediment deltas and shoreline exposure considers these differing reservoir elevations and references the analysis conducted in the 2007 Final EIS.

Reclamation added two new analysis items, similar to the 2024 Final SEIS, to assess impacts on the Colorado River's landscape character and broader landscape character in the Lower Division States. This assessment is based on changes in modeled hydrologic conditions under the No Action Alternative and Continued Current Strategies (CCS) Comparative Baseline, as well as management direction associated with the action alternatives. To assess potential changes to the landscape character along the Colorado River (between Glen Canyon Dam and Lake Mead), this analysis includes a qualitative assessment of effects associated with lower flow rates and the potential inability to conduct HFEs from Glen Canyon Dam. This analysis considers and references the analyses contained in **TA 5**, Geomorphology and Sediment, **TA 9**, Vegetation Including Special Status Species, and **TA 14**, Recreation, which assess the effects of the different flow rates resulting from the alternatives on the prevalence of riparian vegetation, sand bars, and the visibility of river features. Historically, from 1906 to 2007, the average annual natural flow at the Lees Ferry Gaging Station was 14.9 million acre-feet (maf), ranging from 5.4 maf to 24.4 maf. Since the implementation of the Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and

the Coordinated Operations for Lake Powell and Lake Mead (2008 to 2022), the annual natural flow at the Lees Ferry Gaging Station has averaged 12.7 maf, ranging from a low of 6.7 maf (2021) to a high of 20.3 maf (2011). For more information on historic flow rates along the Colorado River, refer to **TA 3**, Hydrologic Resources.

The assessment of potential impacts on the broader landscape character in the Lower Division States considered changes in annual Colorado River water supplies available to these states. This assessment identifies the extent of large-scale changes in visual character in irrigated landscapes, including changes associated with agricultural production. This analysis considers and references assessment items contained in **TA 16**, Socioeconomics, including the effect of each alternative's proposed distribution of water on agricultural operations, as well as the potential for Lake Mead to reach dead pool–related shortages as described in **TA 4**, Water Deliveries. The analysis of impacts on the broader landscape character also considers the effect of increased dust generation from aridification of exposed lands, as described in **TA 7**, Air Quality, potentially impacting visibility and views within GCNP and other visually sensitive landscapes.

Impact Analysis Area

The visual resources impact analysis area was defined as the area within 5 miles of the Colorado River, from Lake Powell to the Southerly International Boundary, including the full pool elevations of Lake Powell and Lake Mead. While the 2007 Final EIS did not specifically identify an analysis area for visual resources, the 2024 Final SEIS identified the same 5-mile-wide analysis area, based on the typical threshold between the Bureau of Land Management's foreground/middle ground distance zone and background distance zone, where views of the change in management could attract attention in the landscape. Visual effects beyond this geographic area were considered, where appropriate, including the potential effects on the broader landscape character associated with potential decreased water availability for the Lower Division States.

Assumptions

- The analysis methods are consistent with the 2007 Final EIS and 2024 Final SEIS. Attraction features analyzed include Cathedral in the Desert, Glen Canyon Dam, and Hoover Dam. Other attraction features, such as Gregory Bridge, La Gorce Arch, and other features currently inundated by Lake Powell, will be mentioned but not analyzed.
- Decreasing flow rates along the Colorado River and the potential inability to conduct HFEs from Glen Canyon Dam would modify the river corridor's natural, visual character by limiting natural flooding processes.
- This Final EIS references the analysis from the 2007 Final EIS and 2024 Final SEIS regarding impacts associated with expanding sediment deltas.
- Decreasing water availability for the Lower Division States would result in large-scale changes to the visual character of irrigated landscapes, including those associated with agricultural production.

Impact Indicators

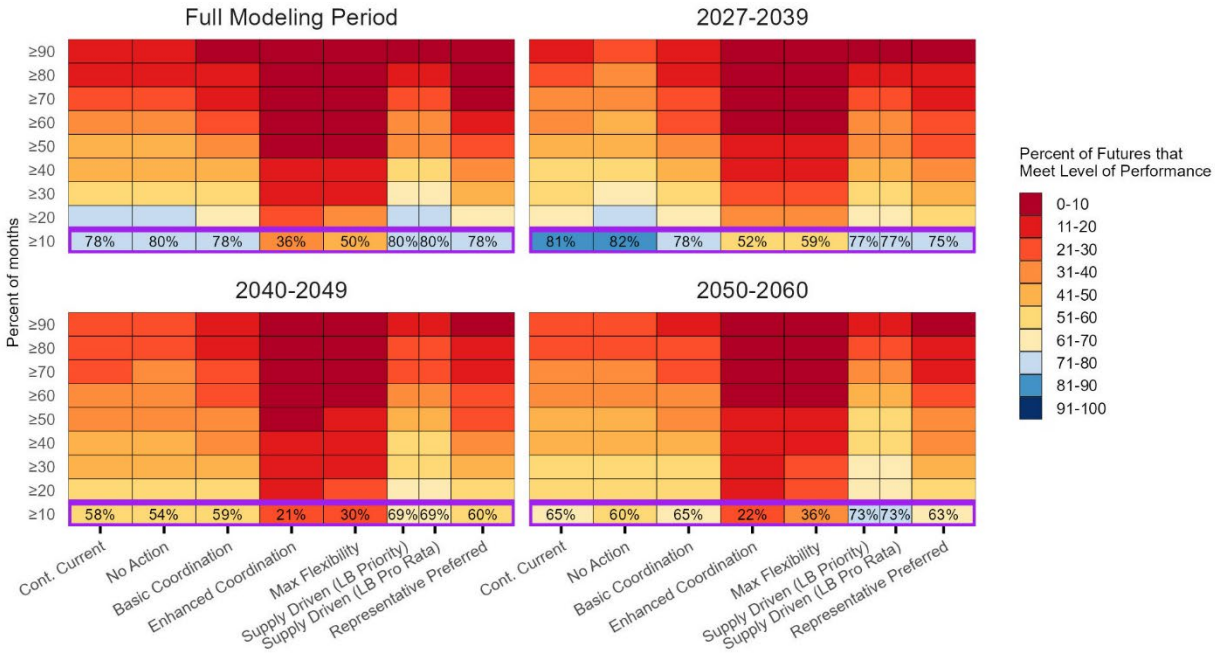
- Attraction Features: Qualitative assessment describing the effects from visibility and access to Cathedral in the Desert, as well as more of Glen Canyon Dam and Hoover Dam becoming visible on their upstream side, informed by the Colorado River Simulation System and DMDU analysis. Quantitative analysis showing the percentage of futures that meet the preferred minimum performance level where Lake Powell is below 3,550 feet (and thus Cathedral in the Desert would be visible and accessible) in at least 10 percent of months under each alternative. Conversely, this analysis identifies the percentage of futures that meet the preferred minimum performance level in which Lake Powell is above 3,550 feet, reducing visibility of the dam's upstream face.
- Calcium Carbonate Rings: Comparison of modeled ring height (feet) at Lake Powell and Lake Mead under each alternative, considering the Colorado River Simulation System and DMDU analyses.
- Exposed Shoreline and Sediment Deltas: Qualitative assessment references the 2007 Final EIS and 2024 Final SEIS, considering differing reservoir elevations under each alternative, to assess receding shorelines and formation of sediment deltas resulting from lower reservoir elevations.
- Colorado River Landscape Character: Qualitative description of the effect associated with proposed flow rates and the potential to conduct HFEs from Glen Canyon Dam under each alternative, considering the modeling presented in **TA 9**, Vegetation Including Special Status Species, **TA 5**, Geomorphology and Sediment, **TA 14**, Recreation, and **TA 7**, Air Quality.
- Broader Landscape Character: Qualitative description of the effects associated with potential decreases in water availability for the Lower Division States on the broader landscape character. This includes considering modeling associated with potential changes to crop production resulting from proposed distribution of water, as described in **TA 16**, Socioeconomics, as well as the potential for Lake Mead to reach dead pool–related shortages as described in **TA 4**, Water Deliveries.

TA 19.2.2 Issue 1: How would management of reservoir elevations affect visibility of attraction features?

The assessment of impacts on landscape character associated with the elevations of Lake Powell considers two concepts. The assessment notes that some visitors view visibility and access to Cathedral in the Desert and other attraction features inundated by Lake Powell (below 3,550 feet) as a benefit, while others prefer higher water levels.. Specifically, some recreationists and other users of this landscape, visibility and access to this feature are important and perceived as an improvement to the area's landscape character. Whereas other recreationists and users may prefer a landscape where water levels are higher, minimizing the impacts on landscape character associated with calcium carbonate rings, exposed shoreline, and sediment deltas (see Issue 2). Historically, Lake Powell has been at or below this elevation approximately 10 percent of the months. As shown in **Figure TA 19-2**, the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches) Alternatives would result in the largest percentage of preferable futures where Cathedral in the Desert is visible and accessible at least 10 percent of the months during the planning period (similar to historic frequency, between 78 percent and 80 percent). The Enhanced Coordination and

Maximum Operational Flexibility Alternatives would have fewer preferable futures where Cathedral in the Desert is visible and accessible at least 10 percent of the months during the planning period, 36 percent, and 50 percent, respectively. The positive influence on landscape character associated with the visibility of Cathedral in the Desert would occur in the most futures under the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as during the full modeling period, except the Enhanced Coordination Alternative, which would perform better with a larger percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative exhibits a similar performance as the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives for the first 10 years (modeled 2027-2039 period), with the results being within the range analyzed associated with these alternatives.

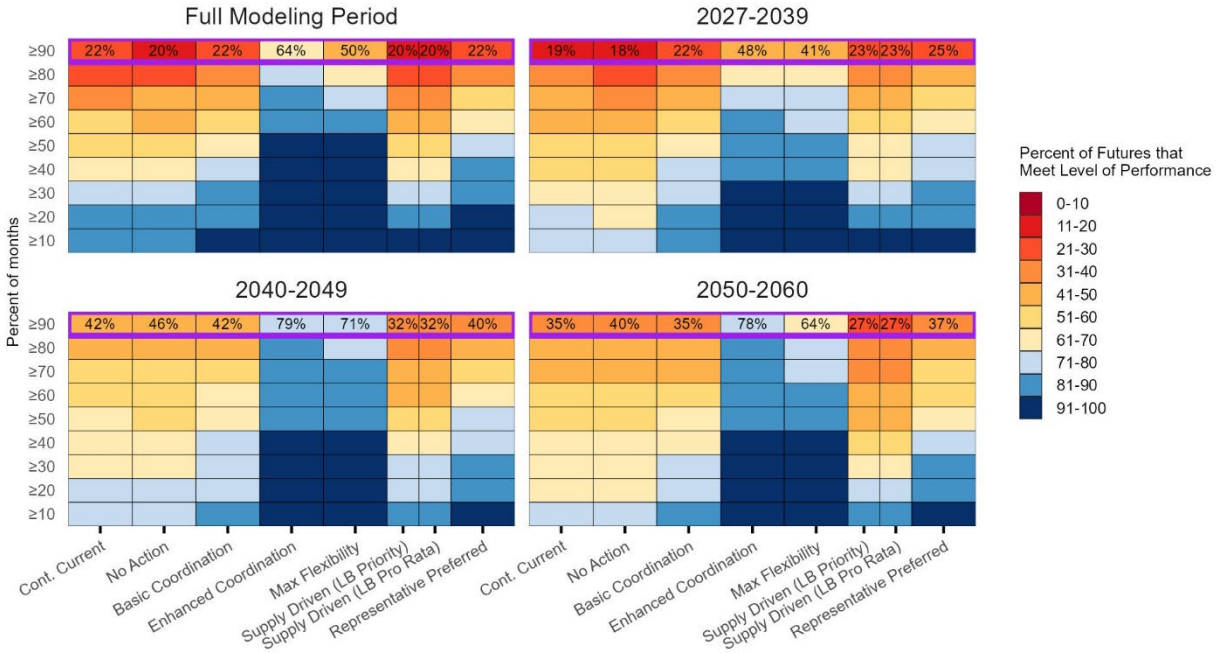
Figure TA 19-2
Visibility and Access to Cathedral in the Desert (and other attraction features inundated by Lake Powell): Robustness.
Percentage of futures in which the elevation of Lake Powell is less than 3,550 feet in the percentage of months specified by each row



The second part of the analysis focuses on keeping the Lake Powell water levels high, which reduces visibility of Glen Canyon Dam, specifically when above 3,550 feet. Therefore, as reservoir levels drop and more of the dam is exposed, its visual prominence increases and can further dominate the surrounding landscape. As shown in **Figure TA 19-3**, the Enhanced Coordination and Maximum Operational Flexibility Alternatives would result in more preferable futures where less of the upstream side of Glen Canyon Dam would be visible, 64 percent and 50 percent, resulting in this

feature being obscured by high water levels. Lower flows could keep Lake Powell at higher elevations under the Enhanced Coordination and Maximum Operational Flexibility Alternatives compared to the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives (between 20 percent and 22 percent). This would result in more preferable outcomes under the Enhanced Coordination and Maximum Operational Flexibility Alternatives, with less of the upstream side of Glen Canyon Dam being visible. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as during the full modeling period except the Enhanced Coordination Alternative, which would have a smaller percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative exhibits a similar performance as the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives for the first 10 years (modeled 2027-2039 period), with the results being within the range analyzed associated with these alternatives.

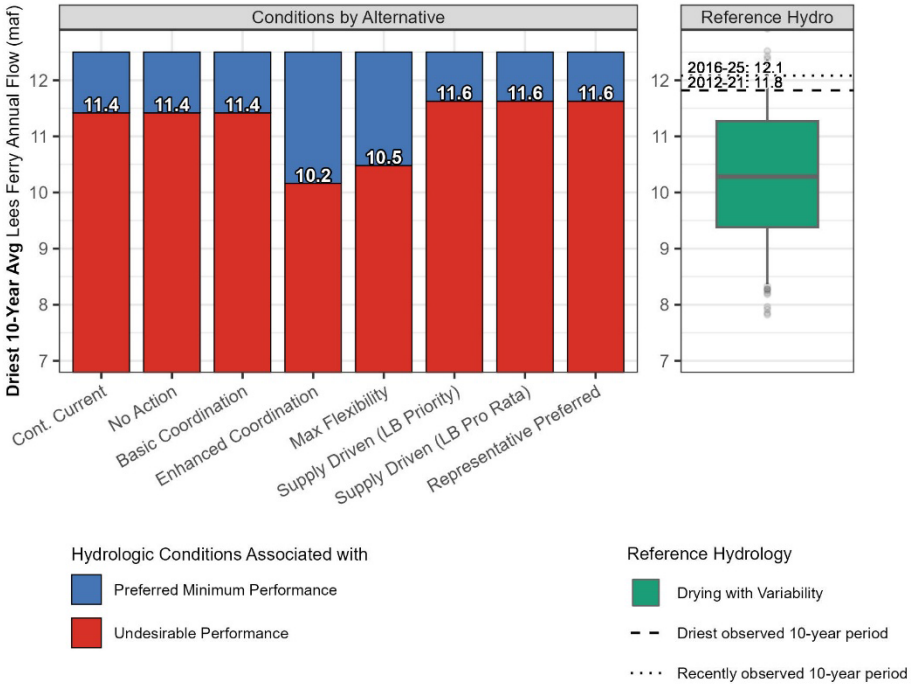
Figure TA 19-3
Limiting the Visibility of Glen Canyon Dam: Robustness.
Percentage of futures in which the elevation of Lake Powell is above 3,550 feet in the percentage of months specified by each row



As shown in **Figure TA 19-4**, comparing DMDU modeling with the driest historic 10-year average Lees Ferry natural flows to identify hydrologic conditions that could cause undesirable performance defined as when Lake Powell is below 3,550 feet for more than 10 percent of the months. The CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would require higher flows to maintain similar elevations, which makes those alternatives more vulnerable to missing the preferred minimum performance

level. Specifically, those alternatives would be more vulnerable than the Enhanced Coordination and Maximum Operational Flexibility Alternatives, with over 75 percent of traces in the reference hydrology exhibiting conditions where Lake Powell could decrease below 3,550 feet for 10 percent or more of months during the planning period. Under the Enhanced Coordination Alternative and Maximum Operational Flexibility Alternative, based on updated modeling, approximately 50 percent of traces in the reference hydrology exhibit conditions that are expected to result in Lake Powell falling below 3,550 feet for 10 percent or more of the planning period. The Representative Preferred Alternative exhibits a similar performance as the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives within the range analyzed under other alternatives.

Figure TA 19-4
Limiting the Visibility of Glen Canyon Dam: Vulnerability.
Conditions that could cause Lake Powell to fall below 3,550 feet in more than 10 percent of months



Modeling of lake levels within Lake Powell and Lake Mead indicates that, under the CCS Comparative Baseline and the No Action, Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternative, Hoover Dam visibility follows the same pattern described for Glen Canyon Dam. Under the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, based on managing higher reservoir levels in Lake Mead compared to Lake Powell, less of the upstream side of Hoover Dam would be visible under these alternatives, with comparatively more of the upstream side of Glen Canyon Dam being visible as described above. Therefore, as reservoir levels decrease, exposing more of the dam's concrete structure, its effect on the area's landscape character would increase and further dominate the landscape character.

TA 19.2.3 Issue 2: How would management of reservoir elevations affect landscape character including visibility of calcium carbonate rings, exposed shoreline, and sediment deltas?

The assessment compares how often modeled futures fall into reservoir elevation ranges relative to full pool and relates those ranges to changes in landscape character. This difference in reservoir elevations creates a light-toned band of calcium carbonate deposit, as well as generating larger sediment deltas and exposing more shoreline. The lower the lake levels become, the impacts on landscape character increase including effects from calcium carbonate rings, exposed shoreline with trash and other debris, and sediment deltas. To compare alternatives, the assessment focused on whether calcium carbonate rings, during the planning period, would exceed historic maximums at any time.

For Lake Powell, the tallest calcium carbonate ring was 179 feet tall, which occurred in February 2023. As shown in **Figure TA 19-5**, **Figure TA 19-6**, and **Figure TA 19-7**, based on updated modeling, all alternatives would exceed the historical maximum during the modeling period. In looking at a higher threshold of 200 feet tall, the CCS Comparative Baseline and the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would result in more futures where the calcium carbonate rings would exceed the 200-foot maximum height during the modeling period with only 5 percent, 4 percent, 13 percent, and 18 percent of futures under these alternatives resulting in calcium carbonate rings being less than 200 feet tall for all the months of modeling. The Enhanced Coordination and Maximum Operational Flexibility Alternatives increase these values to 74 percent and 86 percent. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as the full modeling period except all the action alternatives would result in slightly higher percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative would potentially exceed the 200-foot maximum height, with 45 percent of futures resulting in calcium carbonate rings being less than 200 feet for all months of modeling for the first 10 years (modeled 2027-2039 period) and 24 percent of futures during the full modeling period, with these results within the range analyzed associated with these alternatives.

Figure TA 19-5
Maximum Height of Lake Powell Calcium Carbonate Ring: Robustness.
Percentage of futures in which the monthly calcium carbonate ring at Lake Powell is always less than the height specified by each row

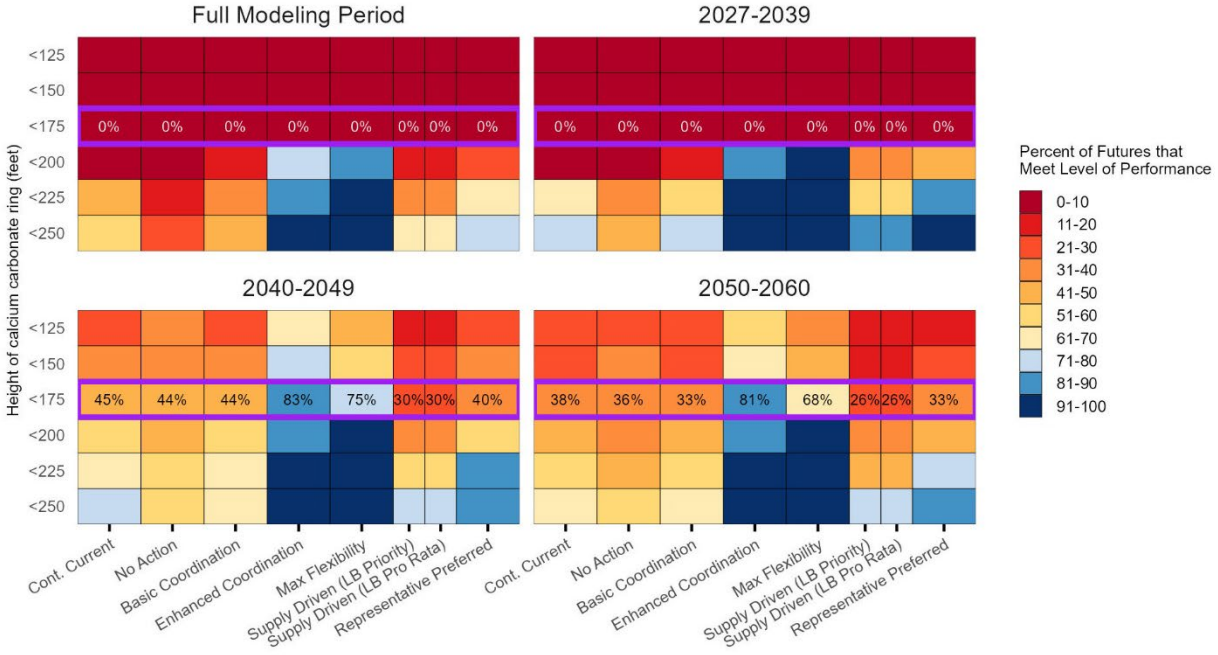


Figure TA 19-6
Monthly Height of Lake Powell Calcium Carbonate Ring Full Modeling Period: Robustness.
Percentage of futures in which the height of the calcium carbonate ring at Lake Powell is less than the reference height in the percentage of months specified by each row

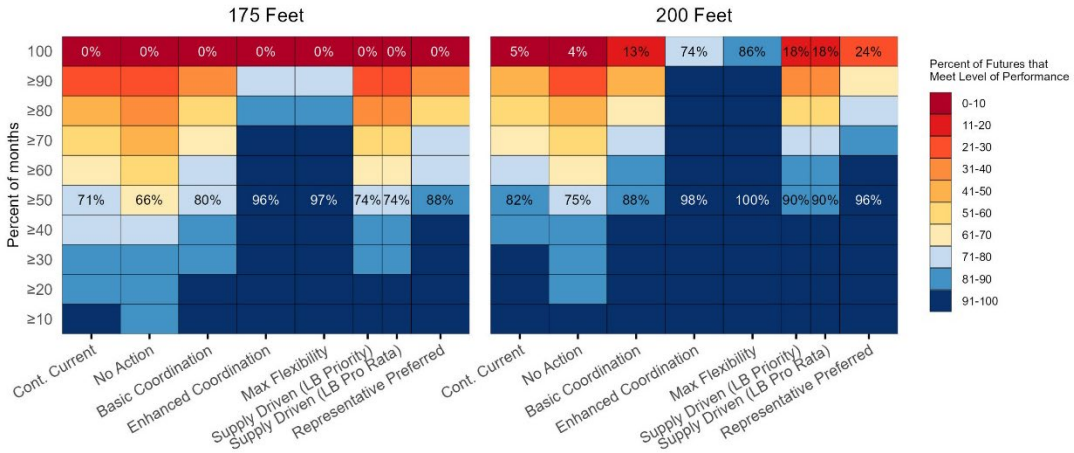
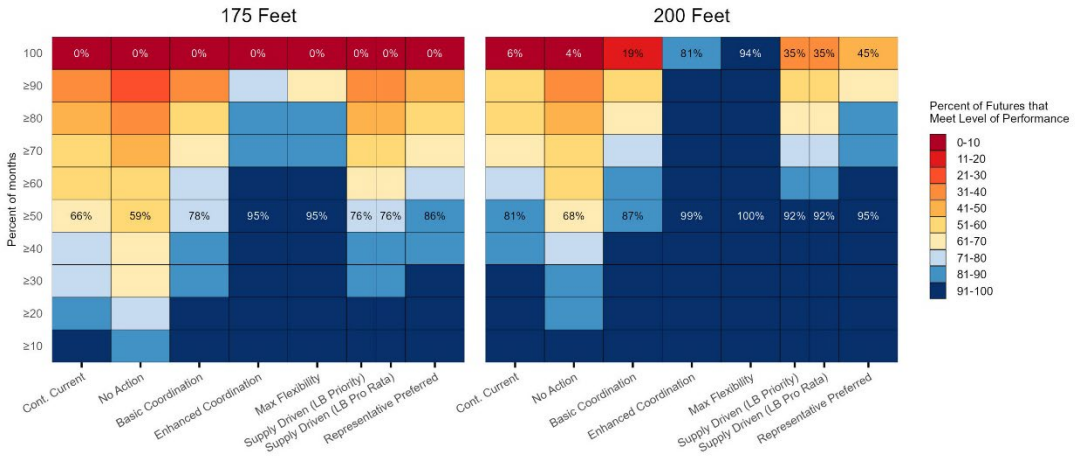
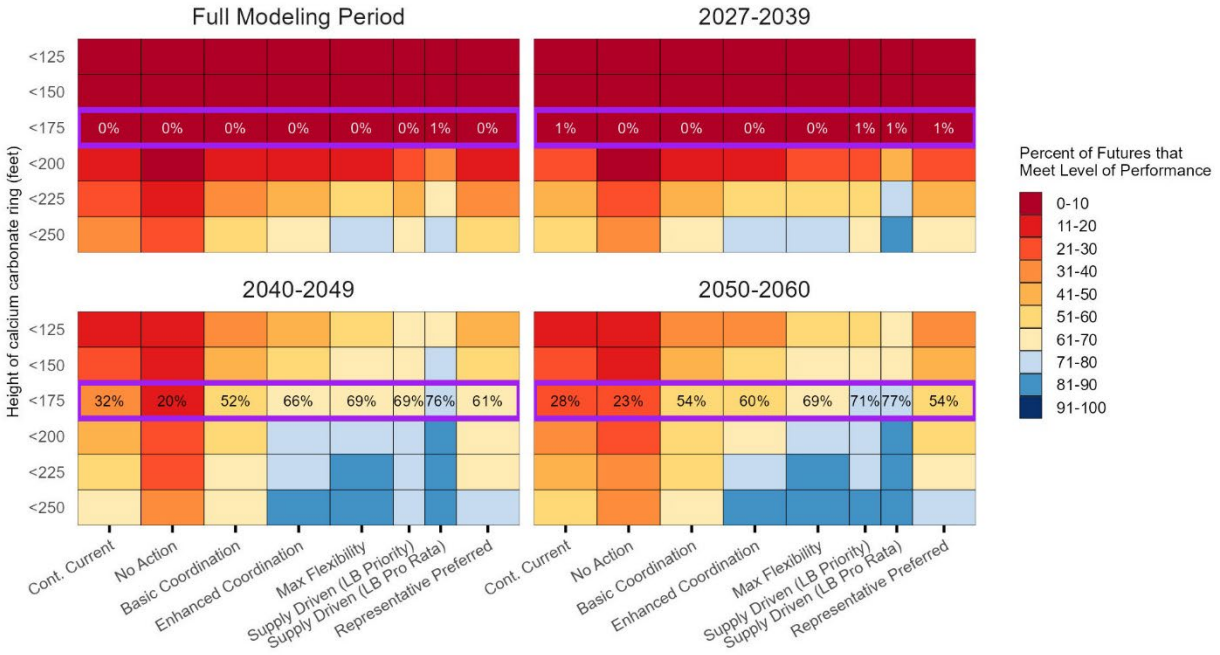


Figure TA 19-7
Monthly Height of Lake Powell Calcium Carbonate Ring 2027-2039: Robustness. Percentage of futures in which the height of the calcium carbonate ring at Lake Powell is less than the reference height in the percentage of months specified by each row



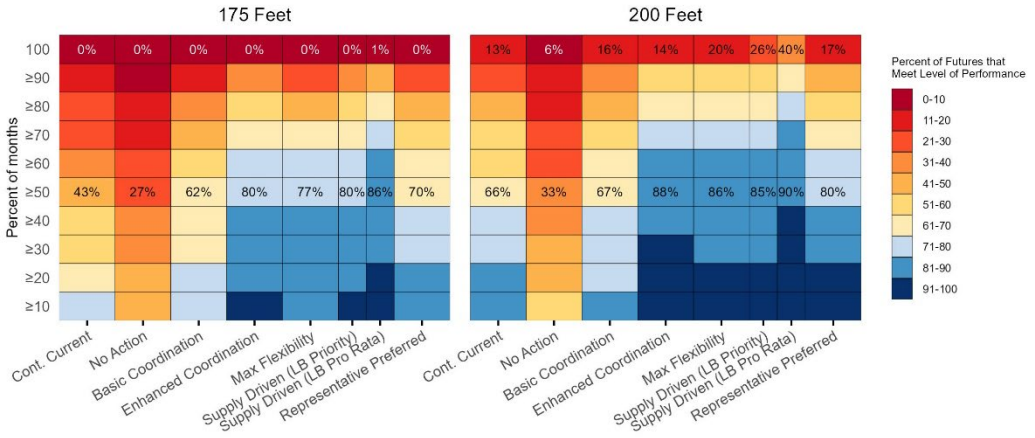
For Lake Mead, the tallest calcium carbonate ring was 180 feet, which occurred in July 2022. As shown in **Figure TA 19-8**, **Figure TA 19-9**, and **Figure TA 19-10**, based on updated modeling, all alternatives would exceed the historical maximum during the modeling period except for the Supply Driven Alternative (LB Pro Rata approach) which would have a 1 percent of futures where this threshold is not exceeded. In looking at a higher threshold of 200 feet tall the CCS Comparative Baseline and the No Action Alternative would result in more futures where calcium carbonate rings would exceed the 200-foot maximum during the modeling period, with only 13 percent and 6 percent of futures under these alternatives resulting in calcium carbonate rings being less than 200 feet tall for all the months of modeling. The Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives increase these percentages to 16 percent, 14 percent, 20 percent, and 40 percent. Considering the first 10 years (modeled 2027-2039), the CCS Comparative Baseline, No Action Alternative, and all action alternatives would have similar results as the full modeling period with all alternatives, including the No Action Alternative, resulting in slightly higher percentage of preferable futures over the first 10 years compared to the full modeling period. The Representative Preferred Alternative would likely exceed the 200-foot maximum height, with 23 percent of futures resuling in calcium carbonate rings being less than 200 feet for all months of modeling for the first 10 years (modeled 2027-2039 period) and 17 percent of futures during the full modeling period, with these results within the range analyzed associated with these alternatives.

Figure TA 19-8
Maximum Height of Lake Mead Calcium Carbonate Ring: Robustness. Percentage of futures in which the monthly calcium carbonate ring at Lake Mead is always less than the height specified by each row



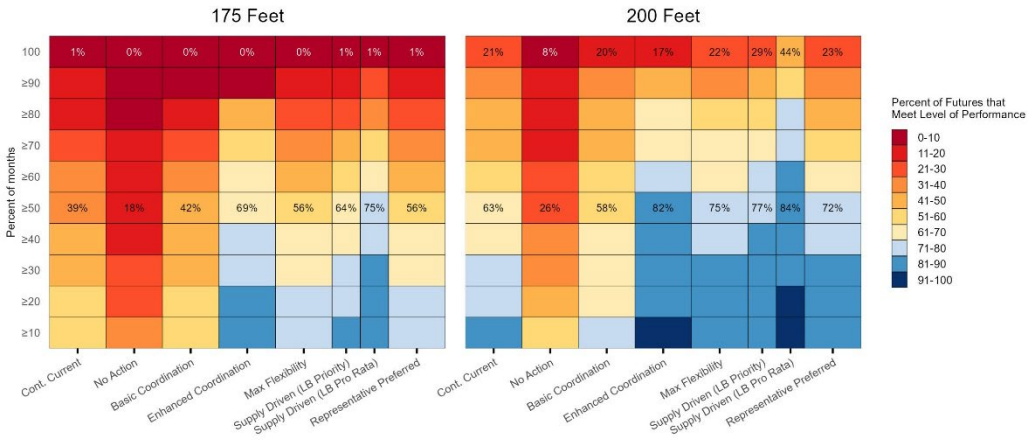
Note: Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Figure TA 19-9
Monthly Height of Lake Mead Calcium Carbonate Ring Full Modeling Period: Robustness.
Percentage of futures in which the height of the calcium carbonate ring at Lake Mead is less than the reference height in the percentage of months specified by each row



Note: Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

Figure TA 19-10
Monthly Height of Lake Mead Calcium Carbonate Ring 2027-2039: Robustness.
Percentage of futures in which the height of the calcium carbonate ring at Lake Mead is less than the reference height in the percentage of months specified by each row



Note: Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water).

As described in the 2007 Final EIS, sediment deltas would continue to build up over time and would be visible as the reservoir elevations decrease, including under the No Action Alternative. The expanding sediment deltas would become populated by vegetation, including tamarisk, which would introduce bright greens into the landscape that contrast with the arid landscapes adjacent to Lake Powell and Lake Mead. Additionally, the receding shorelines would expose trash and other debris, which would diminish the area's landscape character. The lower the lake levels become, impacts on landscape character associated with calcium carbonate rings, exposed shoreline with trash and other debris, and sediment deltas would increase accordingly. Additionally, lower lake levels would facilitate re-emergence of side canyons including public access for recreation (see **TA 14**, Recreation).

Both the calcium carbonate ring, exposed shoreline with trash and other debris, and sediment deltas would modify the landscape character along the edge of Lake Powell. These modifications would be visible for motorists on Utah State Route 95, boaters on Lake Powell, recreationists at developed and undeveloped recreation areas, and hikers on trails adjacent to Lake Powell. Similarly, the calcium carbonate ring, exposed shoreline with trash and other debris, and sediment deltas would modify the landscape character along the edge of Lake Mead; these modifications would be visible for motorists on U.S. Highway 93 (between Boulder City, Nevada, and the Hoover Dam), boaters on Lake Mead (including visitors to Overton Beach and Pearce Ferry), and hikers on trails adjacent to Lake Mead.

TA 19.2.4 Issue 3: How would management of releases from Glen Canyon Dam affect landscape character along the Colorado River?

The No Action Alternative and CCS Comparative Baseline would include lowering releases from Glen Canyon Dam as Lake Powell elevations decrease; this would result in releases as low as 7.0 maf when elevations drop below 3,525 feet. Since neither the No Action Alternative nor the CCS Comparative Baseline includes reducing releases from Glen Canyon Dam under 7.0 maf, including if Lake Powell drops below power pool but remains above dead pool, there would be minor, incremental impacts on the landscape character along the Colorado River, including through the Grand Canyon. The current trends of increasing bank armoring, associated with expanding riparian vegetation areas (including tamarisk), would continue under the No Action Alternative and CCS Comparative Baseline. If the elevation of Lake Powell were to drop below dead pool, flows from Glen Canyon Dam could dramatically decrease, resulting in more extensive impacts on the landscape character, including the appearance of river features previously not visible under current conditions. Additionally, the positive influence of the moving, turbulent Colorado River adds to the existing landscape character, which would be degraded if releases from Glen Canyon Dam were dramatically reduced. The No Action Alternative would result in relatively short and few HFE releases, resulting in fewer opportunities for sand bar volumes to increase compared to the CCS Comparative Baseline, which would result in longer and more frequent HFE releases with more opportunities for increased sand bar volumes as compared to the No Action Alternative.

The Basic Coordination Alternative would result in similar impacts as the No Action Alternative and CCS Comparative Baseline, since it includes a similar range of releases from Glen Canyon Dam, but would include an increased number of futures where HFEs are conducted. The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would include lower releases, as low as 4.7 maf, which is lower than

historic minimum flows. Lower releases from Glen Canyon Dam would result in less water flowing along the Colorado River (and through the Grand Canyon), which could increase existing trends of bank armoring associated with more extensive riparian vegetation, including tamarisk. The Representative Preferred Alternative would also include lower releases, as low as 6.0 maf, which would result in similar impacts along the Colorado River as the other action alternatives but since these releases would result in more water flowing along Colorado River, the trends described above would be tempered. Lower releases also could limit the number of times an HFE could be triggered from Glen Canyon Dam, which would only occur when the HFE furthers maintenance of target reservoir elevations. The Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives would result in the most futures where HFEs are conducted These lower flows may also result in the appearance of river features previously not visible under current conditions and less movement of the river's natural sandbars. If yearly elevations facilitate releases of 7.0 maf or more under the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives, the impact under these alternatives would be similar to those described under the No Action Alternative and CCS Comparative Baseline, as the lower releases from Glen Canyon Dam would be avoided. If the elevation of Lake Powell were to drop below dead pool, flows from Glen Canyon Dam could dramatically decrease, resulting in similar impacts as described under the No Action Alternative and CCS Comparative Baseline. For more information on the impacts on riparian vegetation, refer to **TA 9**, Vegetation Including Special Status Species; for impacts associated with sand bars including their volume, refer to **TA 5**, Geomorphology and Sediment; and for impacts on recreation, including visibility of river features, refer to **TA 14**, Recreation.

TA 19.2.5 Issue 4: How would management of water availability for the Lower Division States affect landscape character?

Since the No Action Alternative includes minor adjustments (0.6 maf) to the distribution of water for Arizona and Nevada (no adjustments for California), based on lowering Lake Mead elevations, there would initially be a limited incremental effect on irrigated landscapes, including those in agricultural use. If elevations in Lake Mead were to drop to dead pool (895 feet), flows from Lake Mead would dramatically decrease, resulting in lower water deliveries than currently allocated, affecting all three Lower Division States. As described in **TA 4**, Water Deliveries, the No Action Alternative would result in the most futures where dead pool–related shortage may be reached during the modeling period. Depending on the duration of these decreased water deliveries, the character of irrigated and agricultural landscapes within the Lower Division States would be modified through aridification of these areas; this would diminish the vivid greens associated with crops and ornamental plantings. The influence of the Colorado River on adjacent lands would narrow as these areas would transition to their natural, arid condition. This would result in large-scale changes to the landscape character compared with the existing condition. Additionally, the aridification of these lands could also result in more exposed soil, generating fugitive dust affecting visibility within the region, including from GCNP and other highly valued viewsheds. For more details on the impacts related to fugitive dust, please see **TA 7**, Air Quality.

CCS Comparative Baseline would include a series of water supply adjustments for the Lower Division States based on lower elevations of Lake Mead. If water levels in Lake Mead drop below 1,075 feet, similar effects as described under the No Action Alternative would occur, with

conservation measures tempering these effects. As lake levels continue to drop toward 1,025 feet, all three states would receive less water from the Colorado River under this alternative through proposed shortages and conservation measures. As Lake Mead approaches dead pool, to avoid a dramatic decrease in water releases from Hoover Dam affecting all three Lower Division States, more reductions could occur (up to 1.38 maf). These include further reductions in water deliveries based on extraordinary circumstances, as described in Section 7(D) of the 2007 Interim Guidelines. These reductions to avoid reaching dead pool would temper the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, as described under the No Action Alternative. If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative.

The Basic Coordination Alternative would have similar impacts as the No Action Alternative as there would be adjustments to the distribution of water for Arizona and Nevada, but no adjustments for California, based on lowering Lake Mead elevations. As Lake Mead elevation drops below 1,160 feet, shortages would begin with those increasing to 1.48 maf when Lake Mead is below 1,110 feet. Through increased shortages under this alternative, the number of futures where Lake Mead reaches dead pool would be reduced compared to the No Action Alternative and CCS Comparative Baseline, but there is still a risk of reaching dead pool under this alternative. As described in **TA 4**, Water Deliveries, the Basic Coordination Alternative would result in the second most futures where dead pool–related shortage may be reached during the modeling period. If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative.

Under the Enhanced Coordination Alternative, there is a potential for larger shortages than proposed under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, with shortages being distributed pro rata among mainstream lower Colorado River water users independent of state. Shortages would begin when Lake Powell effective storage and Lake Mead physical storage are equal to or less than 60 percent of combined capacity and greater than or equal to 30 percent combined capacity, resulting in a 1.3 maf shortage. This would increase to a 3.0 maf shortage when the sum of Lake Powell effective storage and Lake Mead physical storage is less than 30 percent of the combined capacity. These shortages would occur in all three Lower Division States and incrementally affect irrigated landscapes, including those in agricultural use, based on the extent of the shortage. These shortages are designed to avoid reaching dead pool, tempering the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, and avoid more extensive impacts if Lake Mead reached dead pool. As described in **TA 4**, Water Deliveries, the Enhanced Coordination Alternative would result in the second fewest futures where dead pool–related shortage may be reached during the modeling period. If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative.

Under the Maximum Operational Flexibility Alternative, there is a potential for larger shortages than under the CCS Comparative Baseline and the Enhanced Coordination, No Action, and Basic Coordination Alternatives, with shortages being based on priority. These shortages would occur based on the total system effective storage and capacity, as described in **Appendix S**, with shortages up to 4.0 maf. These shortages would occur in all three Lower Division States and

incrementally affect irrigated landscapes, including those in agricultural use, based on the extent of the shortage. These shortages are designed to avoid reaching dead pool, tempering the impacts on the character of irrigated and agricultural landscapes within the Lower Division States and avoid more extensive impacts if Lake Mead reached dead pool. As described in **TA 4**, Water Deliveries, the Maximum Operational Flexibility Alternative would result in the least number of futures where dead pool–related shortage may be reached during the modeling period. If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative.

Under the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), there is a potential for larger shortages than proposed under the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives, with shortages being distributed based on priority within that state or pro rata within that state as described in **Appendix S**. If water levels in Lake Mead drop below 1,145 feet, similar effects as described under the No Action Alternative are anticipated, with conservation measures tempering these effects. As lake levels continue to drop toward 1,000 feet, all three states would receive less water from the Colorado River under this Alternative through proposed shortages, up to 2.1 maf, and conservation measures. These shortages are designed to avoid reaching dead pool, tempering the impacts on the character of irrigated and agricultural landscapes within the Lower Division States, and avoid more extensive impacts if Lake Mead reached dead pool. As described in **TA 4**, Water Deliveries, the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches), similar to the Enhanced Coordination Alternative, would result in the second fewest futures where dead pool–related shortage may be reached during the modeling period. If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative.

The Representative Preferred Alternative would result in shortages up to 3.0 maf, distributed based on Lower Basin consensus arrangements, if they exist, or otherwise distributed based on the priority system, with initial shortages beginning at 1.5 maf in 2027 and 2028. Consultation would occur if Lake Mead elevation were projected to be less than 1,000 feet to determine whether additional reductions are needed in the Lower Basin (including the United Mexican States). As described in **TA 4**, Water Deliveries, the Representative Preferred Alternative, similar to the Enhanced Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, would be in the group of alternatives with the second-fewest futures involving dead pool–related reductions during the modeling period (the Maximum Flexibility Alternative has the fewest futures). If Lake Mead reaches dead pool elevation during the planning period, impacts would be similar to those described under the No Action Alternative. These results are within the range analyzed across the other alternatives. For more information on the impacts on agricultural operations, refer to **TA 16**, Socioeconomics, and for more information on the specific, state-level water deliveries, refer to **TA 4**, Water Deliveries.

TA 19.2.6 Summary Comparison of Alternatives

In general, alternatives that facilitate higher reservoir elevations, maintain higher flows along the Colorado River, including through Grand Canyon, and support full water deliveries to the Lower Division States would result in the lowest impacts on visual resources and on landscape character. While some users may prefer lower lake levels in Lake Powell, to allow Cathedral in the Desert and

other attraction features inundated by Lake Powell to be visible and accessible, in general, higher water levels would result in lower impacts on landscape character, including shorter calcium carbonate rings, less exposed shoreline, including trash and other debris, and smaller sediment deltas.

During wet hydrologic conditions, the range of alternatives would generally produce conditions where lake levels and flows along the Colorado River would result in minimal impacts on landscape character.

As conditions become drier, the No Action Alternative and CCS Comparative Baseline would result in the most futures where landscape character is affected by lower water levels in Lake Powell and Lake Mead compared to the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives. The Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives would result in a similar number of futures as the No Action Alternative and CCS Comparative Baseline with lower water levels in Lake Powell but would keep water levels higher in Lake Mead, similar to the Enhanced Coordination, Maximum Operational Flexibility, and Representative Preferred Alternatives, resulting in more futures where water levels are higher in Lake Powell. The lower the lake levels become, impacts on landscape character associated with calcium carbonate rings, exposed shoreline with trash and other debris, and sediment deltas would increase accordingly.

Under drier conditions, releases from Glen Canyon would be tempered under the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives, which include lower releases to avoid reaching dead pool. While these lower releases would result in incremental impacts on landscape character along the Colorado River, by avoiding dead pool, more intense impacts could be avoided. Under some futures, associated with the CCS Comparative Baseline and No Action Alternative, dead pool may be reached, which would result in flows from Glen Canyon Dam dramatically decreasing, resulting in more extensive impacts on the landscape character, including the appearance of river features previously not visible under current conditions.

Water availability for the Lower Division States associated with the alternatives, under drier conditions, would vary with the No Action Alternative resulting in minimal adjustments to water deliveries from lowering Lake Mead elevations, but if dead pool were reached, flows from Lake Mead would dramatically decrease. This would result in lower water deliveries than currently allocated, affecting all three Lower Division States. Depending on the duration of these decreased water deliveries, the character of irrigated and agricultural landscapes within the Lower Division States would be modified through aridification of these areas, diminishing the influence of the Colorado River on adjacent lands through reduction of vivid greens associated with crops and ornamental plantings. Additionally, the aridification of these lands could also result in more exposed soil, generating fugitive dust affecting visibility within the region, including from GCNP and other highly valued viewsheds. CCS Comparative Baseline and the Basic Coordination, Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives all include more expansive decreased water deliveries which are designed to avoid reaching dead pool, tempering the impacts on the character of

irrigated and agricultural landscapes within the Lower Division States and avoid more extensive impacts if Lake Mead reached dead pool. The Maximum Operational Flexibility, Enhanced Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches), and Representative Preferred Alternatives include the largest potential shortages to minimize the number of future conditions where dead pool could be reached based on DMDU modeling as described in **TA 4**, Water Deliveries.

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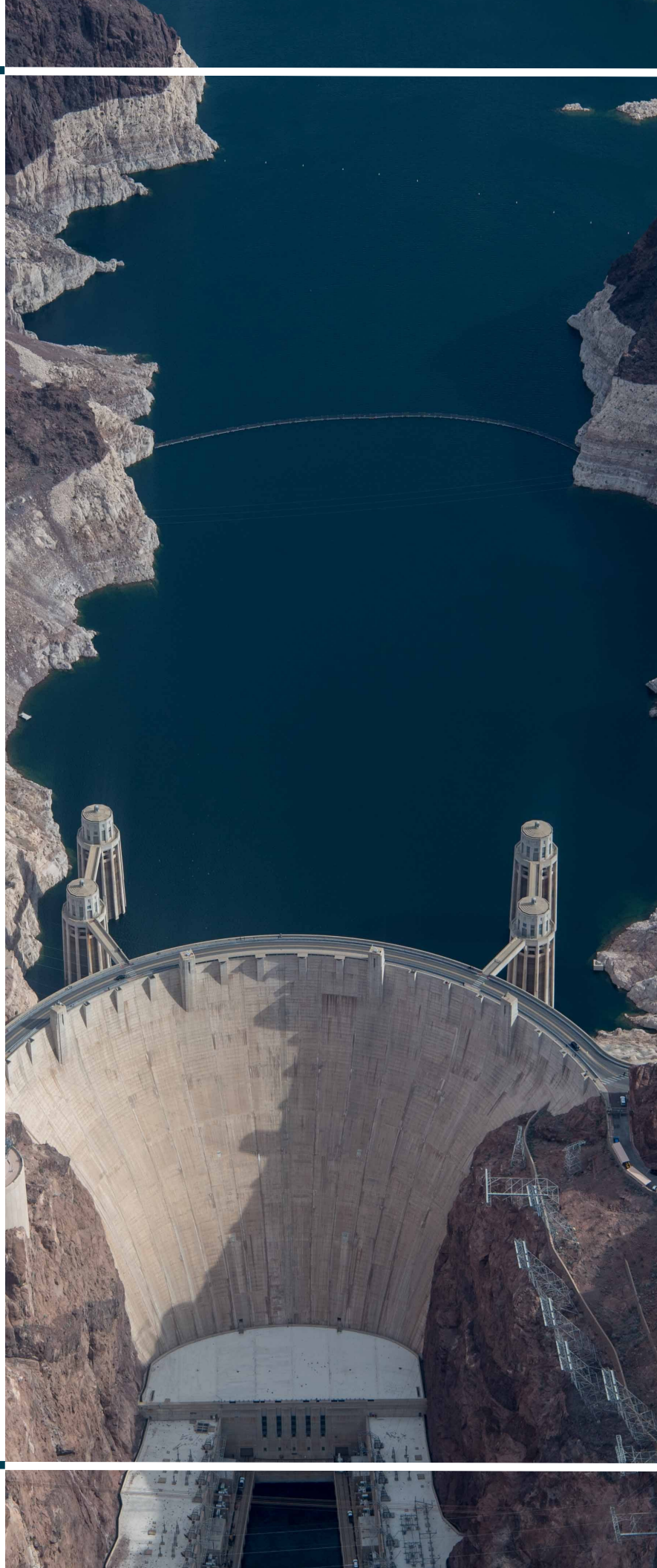
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BUREAU OF
RECLAMATION

Final Environmental Impact Statement



Volume IV: Preparers, References, Glossary, and Index

July 2026
U.S. Department of the Interior
Bureau of Reclamation
Upper and Lower Colorado Basins
Interior Regions 7 and 8

BUREAU OF
RECLAMATION

Mission Statements

The **Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the **Bureau of Reclamation** is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo: Alexander Stephens / Bureau of Reclamation, 2018

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Glossary

acre-foot (af)—Volume of water (43,560 cubic feet) that would cover 1 acre to a depth of 1 foot.

adaptive management—A method for examining alternative strategies for meeting goals and objectives, and then, if necessary, adjusting future management actions according to what is learned.

affected environment—Existing biological, physical, social, and economic conditions of an area that are subject to change, both directly and indirectly, as the result of a proposed human action.

algae—Simple plants containing chlorophyll; most live submerged in water.

algal bloom—An excessive growth of algae in a waterbody, typically associated with nutrient enrichment.

allocation, allotment—Refers to a distribution of water through which specific persons or legal entities are assigned individual rights to consume pro rata shares of a specific quantity of water under legal entitlements. For example, a specific quantity of Colorado River water is distributed for use within each Lower Division State through an apportionment. Water available for consumptive use in that state is further distributed among water users in that state through the allocation. An allocation does not establish an entitlement; the entitlement is normally established by a written contract with the United States government. *Refer to* Lower Basin/Lower Division States.

alluvium—Sedimentary material transported and deposited by the action of flowing water.

ambient—Surrounding natural conditions (or environment) in a given place and time.

amphibian—A vertebrate animal that has a life stage in water and a life stage on land. (Examples include salamanders, frogs, and toads.)

analysis area—Specific geographic boundary and timeframe used to evaluate the potential environmental effects of a proposed action.

anoxic—Describes water conditions in which dissolved oxygen is absent.

annual flow-weighted average concentration—A weighted average of monthly total dissolved solids (TDS) concentrations for a year, where the weight for each month is based on the relative flow for each month.

Annual Operating Plan for Colorado River Reservoirs (AOP)—A document describing how Reclamation will manage Colorado River resources over a 12-month period, consistent with the Long-Range Operating Criteria and the Supreme Court Decree in *Arizona v. California* 1964 . The AOP is prepared annually by Reclamation in cooperation with the Basin States, Mexico, appropriate

federal agencies, Indian tribes, state and local agencies, and the general public, including governmental interests, as required by federal law. As part of the AOP process, the Secretary of the Department of the Interior (Secretary) makes annual determinations regarding the availability of Colorado River water for deliveries to the Lower Division States of the Colorado River Basin. *Refer to* Lower Basin/Lower Division States.

apportionment—Refers to the distribution of water available to each Lower Division State in normal, surplus or shortage condition years, as set forth, respectively, in Articles II(B)(1), II(B)(2), and II(B)(3) of the 1964 Supreme Court Decree in the case of *Arizona v. California. Refer to* normal, surplus, and shortage.

appropriative rights—The right to divert a specified quantity of water at a specified point of diversion for reasonable and beneficial uses at a specified place of use for a specified manner of use. Appropriative rights are generally "first-in-time, first-in-right" (that is, one appropriative right has priority over appropriative rights established later).

backwater—A relatively small, generally shallow area of a river with little or no current.

banked groundwater—Water that has been stored temporarily in a groundwater aquifer. Banked groundwater can be recovered for use at a later time.

base load—Minimum load in a power system over a given period of time.

Basin States—In accordance with the Colorado River Compact of 1922, the Colorado River Basin within the United States consists of those parts of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming within and from which waters drain naturally into the Colorado River. These seven states are referred to as the Basin States. *Refer to* Colorado River Compact of 1922.

bathymetrically—Pertaining to the measurement, mapping, or description of underwater topography.

benthic—Referring to the bottom (bed) of a waterbody.

Binational Intentionally Created Surplus (ICS)—An ICS is a mechanism to encourage and account for augmentation and conservation of water supplies that would minimize the likelihood and severity of potential future shortages. Binational types of ICS are created through the binational agreements of Minutes 319 and 323 to the 1944 Mexican Water Treaty and provide for the development and implementation of water conservation programs located in Mexico with compensation funding provided by partnering organizations in the United States.

biological assessment (BA)—A document identifying the likely effects of a proposed federal action on threatened and endangered species. To facilitate compliance with Section 7(a)(2) of the Endangered Species Act (ESA), federal agencies must prepare a BA pursuant to Section 7(c)(1) of the ESA. *Refer to* Endangered Species Act.

biological opinion (BO)—A document stating the opinion of the United States Fish and Wildlife Service (Service) and/or the National Marine Fisheries Service as to whether a federal action is likely to jeopardize the continued existence of an Endangered Species Act listed threatened or endangered species or result in the destruction or adverse modification of critical habitat.

broodstock—Sexually mature individuals maintained in captivity or managed populations for the purpose of producing offspring.

bug flows—Managed dam releases intended to enhance aquatic invertebrate production and diversity by mimicking natural flow patterns.

bypass flows—Saline agricultural return flows from the Wellton-Mohawk Irrigation and Drainage District that are routed to the Cienega de Santa Clara in Mexico to ensure compliance with the salinity provisions of Minute 242 of the 1944 Water Treaty.

bypass tubes—Another term for river outlet works. *Refer to* outlet works.

candidate species—A plant or animal species that is not yet officially listed as threatened or endangered under the Endangered Species Act but is undergoing status review by the Service.

capacity—The maximum amount of energy that can be instantaneously produced.

catch—At a recreational fishery, refers to the number of fish captured, whether they are kept or released.

channel (watercourse)—An open conduit either naturally or artificially created that periodically or continuously contains moving water, or that forms a connecting link between two bodies of water. Some terms used to describe natural channels are river, creek, run, branch, and tributary. Natural channels may be single or braided. Two terms used to describe artificial channels are canal and floodway.

channel migration—The lateral movement of a river or stream channel across its floodplain over time.

Cladophora—Filamentous green alga important to the food chain in the Colorado River downstream of Glen Canyon Dam.

Colorado River Basin (Basin)—The drainage area of the Colorado River system. The Basin occupies an area of approximately 250,000 square miles in the southwestern United States and 3,500 square miles in northwestern Mexico. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. It also divided the seven states within the Basin into the Upper Division and the Lower Division. Upper Division States include Colorado, New Mexico, Utah, and Wyoming; Lower Division States include Arizona, California, and Nevada. Additionally, 30 federally recognized tribes are in the Basin.

Colorado River Basin Project Act of 1968 (CRBPA)—An act authorizing construction of a number of water development projects, including the Central Arizona Project (CAP), and requiring

the Secretary to develop the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs, or Long-Range Operating Criteria (LROC).

Colorado River Basin Salinity Control Forum—The organization dedicated to controlling Colorado River salinity; it consists of representatives of the seven Basin States. *Refer to* Basin States.

Colorado River Compact of 1922—The agreement concerning the apportionment of the use of the waters of the Colorado River Basin, dated November 24, 1922, and executed by commissioners for Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. It was approved and proclaimed effective by Herbert Hoover, the president of the United States, and representative of the United States for purposes of the Compact, on June 25, 1929.

Colorado River Simulation System (CRSS)—A core Colorado River system operations tool that provides monthly outputs of key variables including reservoir elevations, releases, river flows, and salinity.

Colorado River system—The portion of the Colorado River and its tributaries within the United States as defined in the Colorado River Compact of 1922. *Refer to* Colorado River Compact of 1922.

compact—The Colorado River Compact of 1922. *Refer to* Colorado River Compact of 1922.

compact point—The reference point designated by the Colorado River Compact of 1922 as dividing the Colorado River Basin into two subbasins, the Upper Basin and the Lower Basin. The compact point is Lee Ferry, Arizona. *See also* Colorado River Compact of 1922 and Lee Ferry Compact Point.

conductivity—A measure of water's ability to pass an electrical current.

conservation species—A species that has been identified by a management agency, conservation organization, or research program as needing special attention or protection.

Consolidated Decree—A decree entered by the United States Supreme Court on March 27, 2006, in the case of *Arizona v. California,* 547 US 150 (2006), incorporating all applicable provisions of the earlier-issued decisions and decrees in the matter. The Supreme Court reached a decision in the case of *Arizona v. California* in 1963 and implemented this decision in a 1964 decree, which was supplemented over time after its adoption.

consumptive use—Diversions of water from mainstream Colorado River, including water withdrawn from the mainstream through underground pumping, minus any measured and unmeasured return flows. A use which lessens the amount of water available for another use. Water uses normally associated with man's activities, primarily municipal, industrial, and irrigation uses that deplete water supplies. Water removed from available supplies without direct return to a water resource system, for uses such as manufacturing, agriculture, and food preparation.

contractors—Those who hold entitlements to Colorado River water. Contractors consist of the federal government, states, Indian tribes, and various public and private entities that are recognized

under the Consolidated Decree, hold a Section 5 Contract with the Secretary, or have a Secretarial Reservation of water. *Refer to* Consolidated Decree.

conveyance loss—Water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. If the water is lost due to leakage, it may be considered return flow if it percolates to an aquifer and is available for reuse. If the water evaporates, it is considered consumptive use. *Refer to* consumptive use.

cooperating agency—As described in the National Environmental Policy Act of 1969, as amended, a Federal, State, tribal, or local agency that has jurisdiction by law or special expertise with respect to any environmental impact involved in a proposal (42 U.S.C. 4321 et seq.)

covered species—Those species addressed in the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) for which conservation measures would be implemented and for which authorization for "take" is being requested under Section 10 of the Endangered Species Act. *See also* take.

criteria—Standards used for making a determination.

critical habitat—As defined by the Endangered Species Act, areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species. (16 U.S.C. 1532.Definitions).

cubic foot per second (cfs)—A measure of water flow equal to 1 cubic foot of water passing a point on the stream in 1 second of time.

cultural resource—A building, site, district, structure, or object significant in history, architecture, archaeology, culture, or science.

dead pool—Elevation at which water cannot be regularly released from a reservoir, which would effectively preclude Colorado River diversions to downstream users.

dead storage—Reservoir space from which stored water cannot be evacuated by gravity.

debris fan—A fan-shaped deposit of sediment, rock, and other debris formed when high-velocity flows such as debris flows or flash floods exit a narrow conduit onto a flatter plain.

debris flow—fast-moving mass of water, soil, rock, and organic debris that flows downslope under the influence of gravity.

Decision Making under Deep Uncertainty (DMDU)—A method for making decisions using a framework that evaluates several solutions across multiple future scenarios.

delta sediment—Deposit formed at the mouth of the Colorado River and other rivers where they enter Lake Powell, Lake Mead, or the Gulf of California.

depletion—Loss of water from a stream, river, or basin resulting from consumptive use. *Refer to* consumptive use.

deposition—Settlement of material out of the water column and on to the streambed. Occurs when the energy of flowing water is unable to support the load of suspended sediment.

discharge (flow)—Volume of water that passes a given point within a given period of time; expressed in cubic feet per second (cfs). *Refer to* cubic foot per second.

desiccation—The process of drying out or losing moisture due to exposure to air, heat, or lack of water.

dissolved oxygen (DO)—Amount of free oxygen found in water; perhaps the most commonly employed measurement of water quality. Low DO levels adversely affect fish and other aquatic life. The ideal dissolved oxygen for fish life is between 7 milligrams per liter (mg/L) and 9 mg/L; most fish cannot survive when DO falls below 3 mg/L.

diversion(s)—Colorado River water withdrawn from the mainstream, including water diverted from reservoirs or drawn from the mainstream by underground pumping.

domestic use—Refers to the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes; excludes the generation of electrical power.

downcutting—The process by which a stream or river erodes downward into its bed, deepening the channel through the removal of sediment and bedrock.

draw down—Lowering of a reservoir's elevation; process of depleting a reservoir or groundwater storage.

ecosystem—As defined by the United States Geological Survey (USGS), an ecosystem is made up of all of the living and non-living things in a geographic area. Plants, animals, soil, climate, and other features of the environment interact with each other to form an ecosystem.

electric power system—Physically connected facilities for electricity generation, transmission, and distribution that are operated as a unit under one control.

electrical demand—Energy requirement placed upon a utility's generation at a given instant or averaged over any designated period of time.

electrofishing—A method of sampling fish populations by applying a controlled electric current throughout the water to temporarily immobilize fish for capture, identification, and release.

endangered species—Any species which is in danger of extinction throughout all or a significant portion of its range. as defined by the Endangered Species Act (ESA) of 1973 (16 USC 1532.Definitions). *Refer to* threatened.

Endangered Species Act (ESA)—The Endangered Species Act (ESA) of 1973 (16 USC 1531–1544), establishes protections for fish, wildlife, and plants that are listed as threatened or endangered; provides for adding species to and removing them from the list of threatened and endangered species, and for preparing and implementing plans for their recovery; provides for interagency cooperation to avoid take of listed species and for issuing permits for otherwise prohibited activities; provides for cooperation with States, including authorization of financial assistance; and implements the provisions of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).

endemic—Native to and confined within a particular geographic area or habitat type.

energy—What is produced by powerplants; measured in kilowatt hours.

entitlement—Refers to an authorization to beneficially consume Colorado River water pursuant to a decreed right; a contract with the United States through the Secretary of the Interior or a Secretarial Reservation of water.

entrained—Drawn into and carried along by the movement of water.

ephemeral—Describing a stream that conveys flow only during and shortly after a precipitation event.

epilimnion—Thermal layering of water in lakes and streams. *See also* stratification.

equalization line—the Equalization Tier from the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead defined by an elevation schedule that would be used in determining when equalization releases would be made from Lake Powell.

escapement—Fish moving and surviving through Glen Canyon Dam and into the Grand Canyon.

euryhaline—Describes organisms capable of surviving and functioning across a broad range of salinities.

Extraordinary Conservation Intentionally Created Surplus (ICS)—An ICS is a mechanism to encourage and account for augmentation and conservation of water supplies that would minimize the likelihood and severity of potential future shortages. Extraordinary Conservation types of ICS are created through such conservation measures as fallowing, canal lining programs, and desalination programs.

federally listed species—A species that has been officially designated as endangered or threatened.

fish barrier—Any natural or artificial structure that prevents or limits the upstream or downstream movement of fish.

firm energy or power—Non-interruptible energy or power guaranteed by the supplier to be available at all times except for reasons of uncontrollable forces or "continuity of service" contract provisions.

flood—An overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a river or stream. A relatively high flow as measured by either gage height or discharge quantity.

flood control pool—Reservoir volume above the active conservation and joint-use pool that is reserved for flood runoff and then evacuated as soon as possible to keep that space ready for the next flood.

flood control release—The release of water from Lake Mead and the operation of Hoover Dam for flood control purposes pursuant to the reservoir operating criteria specified in the February 8, 1984, Field Working Agreement between the United States Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation), and the USACE regulations contained in 33 Code of *Federal Regulations* (CFR) 208.11.

flow—Volume of water passing a given point per unit of time expressed in cubic foot per second. *See also* cubic foot per second.

forage fish—Generally, small fish that reproduce prolifically and are consumed by predators.

fore bay—Impoundment immediately above a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (storage, run-of-river, and pumped storage).

Fossil—Any remains, trace, or imprint of a plant, animal, or other organism that has been preserved in the geologic record. Fossils can include body fossils (for example, bones, teeth, shells, and leaves), trace fossils (for example, tracks, trails, burrows, coprolites, and chemical signatures), and various kinds of microfossils (for example, pollen grains, spores, and diatoms). Fossils are generally considered to be older than about 11,700 years (the end of the Pleistocene Epoch), but remains older than middle Holocene age (about 5,000 years) can also be considered to represent fossils because they are part of the record of past life.

fry—Life stage of fish between the egg and fingerling stages.

full pool—Volume of water in a reservoir at maximum design elevation.

gaging station—Specific location on a stream where systematic observations of hydrologic data are obtained through mechanical or electrical means.

gigawatt-hour (GWh)—One billion watt-hours of electrical energy.

grow-out—The stage in aquaculture or fish culture during which young fish are raised to a larger or more mature size until they are ready for release.

habitat conservation plan (HCP)—A planning document describing general and species-specific conservation measures for species listed under the Endangered Species Act.

headwater—The source and upper part of a stream.

hepatotoxins—Toxins that damage or interfere with liver functions.

high-flow experiments (HFEs)—Scheduled releases of water from a dam above powerplant capacity to benefit key resources by simulating pre-dam floods.

historic property—Any district, site, building, structure, or object listed on or eligible for listing on the National Register of Historic Places (36 CFR 800.16(l)(1)).

hydropower—The use of water to produce electricity.

hypolimnetic zone—The deep portion of a lake or reservoir volume generally classified as below the level of the thermocline. *Refer to* thermocline.

hypolimnion—Thermal layering of water in lakes and streams; the lower stratum of the water column of a reservoir. This layer is generally undisturbed, and respiration and decomposition predominate. *Refer to* stratification.

important farmlands—Prime farmland, unique farmland, farmland of statewide importance, and farmland of local importance, as defined by the United States Department of Agriculture Natural Resources Conservation Service (formerly the Soil Conservation Service). The categorization of farmland is based on a soil classification system that accounts for the physical and chemical characteristics of the land and the suitability of the land for producing crops. Important farmlands are afforded special protection due to their importance to agricultural production.

Imported Intentionally Created Surplus (ICS)—An ICS is a mechanism to encourage and account for augmentation and conservation of water supplies that would minimize the likelihood and severity of potential future shortages. Imported types of ICS are created by introducing non-Colorado River System water in that entitlement holder's state into the mainstream.

impoundment—Body of water created by a dam.

in situ—In archaeology, and as used in this EIS, an artifact that has not been moved from its original place of deposit.

Indian trust assets (ITAs)—An Indian trust asset is something the Federal government holds in trust for the benefit of a Native American individual or tribe. In the case of trust lands, this means that an individual or tribe earns money when companies lease rights to that land and earn income.

inflow—Water flowing into a lake or reservoir from a river and/or its tributaries, or water entering a river from tributaries.

inundated—Covered or submerged by water.

irrigated area—The gross farm area upon which water is artificially applied for the production of crops, with no reduction for access roads, canals, or farm buildings.

irrigation—The controlled application of water to arable lands to supply water requirements not satisfied by rainfall.

juvenile—Young fish older than 1 year but not having reached reproductive age.

kilowatt-hour (kWh)—One thousand watt-hours of electrical energy.

land cover type—A classification system to describe vegetation and other habitat types (such as cottonwood willow, honey mesquite, and marsh).

landscape character—Overall visual appearance of a given landscape based on the form, line, color, and texture associated with the landscape's vegetation, landforms/water, and human-made modifications. These factors give the area a distinctive quality that distinguishes it from its immediate surroundings.

Las Vegas Valley—The topographic basin containing the city of Las Vegas, the city of North Las Vegas, the city of Henderson, and certain unincorporated townships of Clark County in the State of Nevada.

Las Vegas Wash—The natural drainage channel for the entire Las Vegas Valley. It is dominated by wastewater flows from the city of Las Vegas, Clark County Sanitation District, and city of Henderson wastewater treatment plants. It terminates in the Las Vegas Bay of Lake Mead in the State of Nevada.

Law of the River—As applied to the Colorado River, a body of documents the Secretary of the Interior (Secretary) uses to carry out the responsibility to manage the mainstream waters of the Lower Basin pursuant to applicable federal law. The Secretary is vested with this responsibility. This collective set of documents is comprised of numerous operating criteria, regulations, and administrative decisions from federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts. The Secretary apportions the Colorado River waters and regulates the use and management of the Colorado River among the seven Basin States and Mexico. *Refer to* Colorado River Compact of 1922 and Basin States.

lead agency—An agency initiating and overseeing the preparation of an EIS. For this EIS, Reclamation is the lead agency for compliance with NEPA.

Lee Ferry Compact Point—Identified reference point that marks the division between the two subbasins—the Upper Basin and the Lower Basin—created by the division of the Colorado River Basin in the Colorado River Compact of 1922. This reference point is in the mainstream Colorado

River in Arizona, one mile below the confluence of the Colorado River with the Paria River. *Refer to* Colorado River Compact of 1922.

Lees Ferry Gaging Station—The site of the United States Geological Survey (USGS) stream gage (Lees Ferry Gaging Station) in Arizona on the Colorado River upstream of its confluence with the Paria River, downstream of Glen Canyon Dam. Also, the location of Colorado River ferry crossings (1873 to 1928).

limitrophe—a border state or area.

limnology—Scientific study of physical characteristics and the biology of lakes, ponds, and streams.

littoral—The shallow, nearshore zone of a lake or reservoir.

load—Amount of electrical power or energy delivered or required at a given point.

Lower Basin (States)—Those parts of the states of Arizona, California, Nevada, New Mexico, and Utah within and from which waters drain naturally into the Colorado River below the Lee Ferry Compact Point in Arizona. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. *See also* Lee Ferry Compact Point.

Lower Division (States)—Arizona, California, and Nevada. The Colorado River Compact of 1922 divided the seven Colorado River Basin states into two groups: Upper Division States and Lower Division States. The Lower Division States are Arizona, California, and Nevada. *See also* Basin States.

mainstream—The primary channel of a river system carrying the largest and most continuous flow.

magnitude—A number characteristic of a quantity and forming a basis for comparison with similar quantities, such as flows. *Refer to* flows.

mean monthly flow—Average flow for the month, usually expressed in cubic feet per second.

mean sea level (msl)—The average height of the surface of the oceans and seas measured throughout all stages of the tidal cycle, determined from hourly readings of tidal height, and computed over a long (usually 19-year) period. It is used as a datum plane (that is, it serves as the reference surface from which elevations and depths are measured).

median—Middle value in a distribution, above and below which lie an equal number of values.

megawatt (MW)—One million watts of electrical power (capacity).

megawatt-hour (MWh)—One million watt-hours of electrical energy.

mesolimnion—The middle layer in a stratified lake or reservoir.

Mesozoic era—The second-to-last era of earth's geological history, lasting from about 252 to 66 million years ago, comprising the Triassic, Jurassic, and Cretaceous periods.

metalimnion—Thermal layering of water in lakes and streams. *Refer to* stratification.

milligram per liter (mg/L)—As defined by the United States Geological Survey (USGS), a unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (ppm).

minimum power pool—The reservoir elevation below which water can no longer produce power because the water does not reach the intakes for hydropower generation.

monomictic—Describes a lake or reservoir that undergoes complete mixing once a year, usually because of seasonal changes in air and water temperature.

National Critical Infrastructure—those assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof. Presidential Policy Directive 21 (PPD-21): Critical Infrastructure Security and Resilience advances a national policy to strengthen and maintain secure, functioning, and resilient critical infrastructure.

National Environmental Policy Act of 1969, as amended (NEPA) (43 U.S.C. 4321 et seq.)—As described on the Department of Energy's NEPAnet web site, NEPA requires Federal agencies to assess the environmental effects of proposed major Federal actions prior to making decisions. Section 101 of NEPA sets forth a national policy "to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans." 42 U.S.C. 4331(a). Section 102 of NEPA establishes procedural requirements, applying that national policy to proposals for major Federal actions significantly affecting the quality of the human environment by requiring Federal agencies to prepare a detailed statement on: (1) the environmental impact of the proposed action; (2) any adverse effects that cannot be avoided; (3) alternatives to the proposed action; (4) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and (5) any irreversible and irretrievable commitments of resources that would be involved in the proposed action. (42 U.S.C. 4332(2)(C)).

National Register of Historic Places (NRHP)—The Nation's official list of historic places worthy of preservation. Authorized under the National Historic Preservation Act of 1966, the NRHP is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archaeological resources. Properties listed on the NRHP include districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, engineering, and culture.

natural flow—The flow of any stream un-depleted by human activities.

neurotoxins—Toxic substances that interfere with the normal function of the nervous system.

non-system water—Waters originating from outside the Colorado River system.

normal condition—When the Secretary has determined that there is available for annual release 7.5 million acre-feet (maf) to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(1) of the Consolidated Decree. *Refer to* Lower Division States and Consolidated Decree.

oligotrophic—A body of water characterized by low dissolved plant nutrient and organic matter, and rich in oxygen at all depths.

outlet works—A combination of structures and equipment required for the safe operation and control of water released from a reservoir to serve various purposes, i.e., regulate stream flow and quality; release floodwater; and provide irrigation, municipal, and/or industrial water. Included in the outlet works are the intake structure, conduit, control house-gates, regulating gate or valve, gate chamber, and stilling basin. A series of components located in a dam through which normal releases from the reservoir are made. A device to provide controlled releases from a reservoir. A pipe that lets water out of a reservoir, mainly to supply downstream demands.

Paleontological resources—Any fossilized remains, traces, or imprints of organisms preserved in or on the earth's crust.

Paleontology—The study of life in past geologic time based on fossil remains, including their anatomy, phylogeny, ecology, relationships to existing plants, animals, and environments, and the chronology of the earth's history.

Paleozoic era (541–252 million years ago)—Means ancient life. The oldest animals on earth appeared just before the start of this era.

Pangea—A supercontinent that existed from about 300 to 200 million years ago and included most of the continental crust of the earth.

peak flow—Maximum instantaneous flow in a specified period of time.

peak load—Maximum electrical demand in a stated period of time.

pelagic—Relating to the open-water zone of a lake or reservoir, away from the shore and bottom.

penstock—Conduit pipe used to convey water from the reservoir through the dam under pressure to the turbines of a hydroelectric plant.

percentile—A statistical term. A descriptive measure that splits ranked data into 100 parts, or hundredths. For example, the 10th percentile is the value that splits the data in such a way that 10 percent of the values are less than or equal to the 10th percentile.

piscivorous—Habitually feeding on fish.

PIT scanning—The process of detecting and recording Passive Integrated Transponder (PIT) tags implanted in fish using an electronic reader.

PM_{10} (PM10)—Particulate matter (PM) (dust particles) standard that includes particles with a diameter of 10 micrometers or less.

$PM_{2.5}$ (PM2.5)—Particulate matter (PM) (dust particles) standard that includes particles with a diameter of 2.5 micrometers or less.

power—Electrical capacity generated, transferred, or used.

Present Perfected Right (PPR)—Many Colorado River water rights that originated as "perfected rights" specified in the 1964 United States Supreme Court Decree in the case of *Arizona v. California.* PPRs are the highest-priority Colorado River water rights that the 1964 Decree defines as those perfected rights existing on June 25, 1929 (the effective date of the Boulder Canyon Project Act of 1928). *Refer to* Consolidated Decree.

priority—A ranking with respect to diversions of water relative to other water users.

pro rata shortage distribution—distribution of policy shortages on a proportional basis (i.e., at the same percentage reduction from each user's entitlement) across all Lower Basin water users, including Mexico.

probability—The relative frequency with which a range of modeled values occurs.

propagule—Various forms of reproductive material (e.g., smallmouth bass larvae).

public involvement—Process of obtaining citizen input during each stage of development of planning documents. For EISs, NEPA requires Federal agencies, "…*request public comment on alternatives or impacts and on relevant information, studies, or analyses with respect to the proposed agency action."* (43 U.S.C. 4321 et seq).

Quaternary period—A geologic time period that encompasses the most recent 2.6 million years, including the present day.

ramp rate—The rate of change in instantaneous output from a powerplant. The ramp rate is established to prevent undesirable effects due to rapid changes in loading or, in the case of hydroelectric plants, discharge.

rated head—Water depth for which a hydroelectric generator and turbines were designed.

reach—A specified segment of a river, stream, channel, or other water conveyance.

rearing—The period in which juvenile fish grow and develop before migrating or recruiting into older life stages.

recruitment—Survival of young plants and animals from birth to a life stage less vulnerable to environmental change.

refuge ponds—Off-channel or low-flow ponded areas that provide shelter for fish during unfavorable conditions such as high temperatures or low flows.

remote sensing—The collection and interpretation of information about the earth's surface or atmosphere without direct physical contact.

repatriated—Refers to the intentional reintroduction of a species into an area of its historical range from which it has been locally extinct.

reregulating reservoir—A reservoir for reducing diurnal fluctuations resulting from the operation of an upstream reservoir for power production.

resampling—The digital process of changing the sample rate or dimensions of sampled data (for example, digital imagery or audio) by temporarily or areally analyzing and sampling the original data.

reserved water—In the case of Indian reservations, rights based on the doctrine of Indian reserved rights; in the case of federal establishments other than Indian reservations, a federal reservation of water for use on property under federal jurisdiction.

reservoir—A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

resilience—The capacity of a species to absorb disturbance, maintain essential functions, and recover to a stable condition within a reasonable amount of time.

return flow—The portion of water previously diverted from a river or stream and subsequently returned to that river or stream and is available for consumptive use by others. *Refer to* consumptive use.

return flow credit—In the accounting of consumptive use in the Lower Basin, Colorado River water that is returned to the river and is available for consumptive use by others in the year in which it was diverted and is credited against a water user's total diversions. *Refer to* consumptive use.

riffle—A stretch of choppy water caused by an underlying rock shoal or sandbar.

riparian—Of, on, or pertaining to the bank of a river, pond, or lake.

river mile (RM)—A unit of measurement (in miles) used on rivers. For the purposes of this EIS, river miles are numbered along the Colorado River from south to north starting with RM 0.0 at the Southerly International Boundary (SIB) with Mexico. Dam locations are noted at their respective river miles.

river outlet works—Dam structures that conduct water from the reservoir to the river without passing through a powerplant; also referred to as jet tubes, bypass tubes, or outlet works. *Refer to* bypass tubes and outlet works.

river stage—Water surface elevation of a river above a datum. As described by the United States Geological Survey, river stage is an important concept when analyzing how much water is moving in a stream at any given moment. Stage is the water level above some arbitrary point, usually with the zero height being near the river bed, in the river and is commonly measured in feet.

riverine—Relating to or characteristic of a river or stream.

RiverWare™—A commercial river system simulation computer program that was configured to simulate operation of the Colorado River.

robustness—The degree to which a model or conclusion remains valid and reliable under different assumptions, datasets, or analytical conditions.

runoff—That part of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of humans in or on the stream channels.

sacred site—A specific location identified by a Native American tribe as sacred for its religious significance to, or ceremonial use by, a Native American religion.

salinity—Saltiness. The relative concentration of dissolved salts, usually sodium chloride, in a given water supply. A measure of the concentration of dissolved mineral substances in water.

sandbar—A long, narrow deposition of sediment within a river.

Secretary—The Secretary of the Department of the Interior.

sediment—Any finely divided organic and/or mineral matter deposited by air or water in nonturbulent areas. Unconsolidated solid material that comes from weathering of rock and is carried by, suspended in, or deposited by water or wind.

sediment load—Mass of sediment passing through a stream section in a specified period of time, expressed in millions of tons (mt). Amount of sediment carried by running water. The sediment that is being moved by a stream.

seepage—The slow movement or percolation of water through soil or rock. Movement of water through soil without formation of definite channels. The movement of water into and through the soil from unlined canals, ditches, and water storage facilities. The slow movement or percolation of water through small cracks, pores, interstices, etc., from an embankment, abutment, or foundation.

shortage condition—When the Secretary of the Interior has determined that there is available for annual release less than 7.5 maf to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(3) of the Consolidated Decree. *Refer to* Lower Division States and Consolidated Decree.

sonic tagged—Describes a fish that has been implanted with or attached to an acoustic sounder that emits sound pulses and can be detected by receivers to track movement and habitat use.

spawn—To lay eggs, especially fish.

spills—Water releases from a dam in excess of powerplant capacity.

spillway—A structure that passes normal and/or flood flows in a manner that protects the structural integrity of the dam. Overflow channel of a dam or impoundment structure. A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway. Any passageway, channel, or structure designed to discharge surplus water from a reservoir.

spinning reserves—Available capacity of generating facilities synchronized to the interconnected electric system so that it can be called upon for immediate use in response to system problems or sudden load changes.

stage—Same as elevation or depth of water. The height of a water surface above an established datum.

standards—A means established by authority as a rule for the measure of quality, such as cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

State-regulated sportfish—Fish species managed by a state natural resource or wildlife agency for recreational fishing.

stocked—Describes fish that have been intentionally introduced into a waterbody.

storage—Water artificially impounded in surface or underground reservoirs for future use. Water naturally detained in a drainage basin, such as groundwater, channel storage, and depression storage. The term "drainage basin storage" or simply "basin storage" is sometimes used to refer collectively to the amount of water in natural storage in a drainage basin. *See also* conservation storage and dead storage.

stormwater—Consists of water that originates from precipitation, such as heavy rain or snow.

stratification—Thermal layering of water in lakes and streams. Lakes usually have three zones of varying temperature: (1) epilimnion—top layer with essentially uniform warmer temperature, (2) metalimnion—middle layer of rapid temperature decrease with depth, and (3) hypolimnion—bottom layer with essentially uniform colder temperatures.

streamflow—The discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than runoff, as streamflow may be applied to discharge whether it is affected by diversion or regulation.

suspended load—Sediment that is supported by the upward components of turbulence in a stream and that stays in suspension for an appreciable length of time.

surplus condition—When the Secretary of the Interior has determined that there is available for annual release more than 7.5 maf to satisfy consumptive use in the Lower Division States pursuant to Article II(B)(2) of the Consolidated Decree. *Refer to* Lower Basin/Lower Division States and Consolidated Decree.

system conservation—A voluntary reduction of consumptive use of Colorado River water that can be estimated or measured. *Refer to* consumptive use.

System Efficiency Intentionally Created Surplus (ICS)—An ICS is a mechanism to encourage and account for augmentation and conservation of water supplies that would minimize the likelihood and severity of potential future shortages. System Efficiency types of ICS are created when an entitlement holder makes a capital contribution to the Secretary of the Interior for use in funding projects designed to realize system efficiencies that save water that would otherwise be lost from the mainstream of the United States.

system storage—The total volume of water available in the Colorado River Basin at a specific point in time.

system water—Waters originating from the Colorado River system. *Refer to* Colorado River system.

tail water—Water immediately downstream of the outlet from a dam or hydroelectric powerplant where the water is more similar to that in the reservoir than farther downstream.

take—To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct as defined by the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1532.Definitions).

talus—An accumulation of loose, angular rock fragments that collect at the base of cliffs or steep valley walls.

thermocline—The zone of maximum change in temperature in a waterbody, separating upper (epilimnetic) from lower (hypolimnetic) zones.

trammel-netting—A fish sampling technique that uses a three-layered gill net designed to capture fish of various sizes.

threatened species—A species or subspecies that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range as defined by the Endangered Species Act (ESA) of 1973 (16 USC 1532.Definitions). *Refer to* endangered.

total dissolved solids (TDS)—Dissolved materials in the water, including ions such as potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium. In many instances, the term "TDS" is used to reflect salinity, since these ions are typically in the form of salts.

traces—Multiple time series of forecasted streamflow used in hydrological modeling. Multiple traces are sometimes referred to as an ensemble.

traditional cultural place—A type of historic property that is rooted in a community's history and important to that community's cultural identity.

tributary—River or stream flowing into a larger river or stream.

turbidity—Cloudiness of water, measured by how deeply light can penetrate into the water column from the surface.

turbine—A rotary mechanical device that uses water flow to turn and convert it into energy.

Upper Basin (States)—Those parts of the states of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters drain naturally into the Colorado River above the Lee Ferry Compact Point in Arizona. The Colorado River Compact of 1922 divided the Colorado River system into two subbasins: the Upper Basin and the Lower Basin. *Refer to* Lee Ferry Compact Point.

Upper Colorado River Commission—Commission established by the Upper Colorado River Compact of appointed members from the Upper Division States whose purpose is to secure the storage of water for beneficial consumptive use in the Upper Basin.

Upper Division (States)—Colorado, New Mexico, Utah, and Wyoming. The Colorado River Compact of 1922 divided the seven Colorado River Basin states into two groups: Upper Division States and Lower Division States. The Upper Division States are Colorado, New Mexico, Utah, and Wyoming. *Refer to* Basin States and Lower Division (States).

varial zone—The zone along the margins of a river or lake that alternates between submerged and exposed due to changes in water level.

visual resources—Physical features that make up the visible landscape (features such as land, water, vegetation, topography, and human-made features such as buildings, roads, utilities, and structures) as well as the response of viewers to those features.

Water Year (WY)—Period of 12 months ending September 30 of each year.

watershed—The drainage area upstream of a specified point on a stream.

young-of-year—Fish that were born or hatched during the current year.

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